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1986

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13. ABSTRACT (Maximum 200 words)

The Bird Strike Committee Europe consists of civil and military participants from Europe with a common interest in the bird strike problem. Attendence is open to participants from other parts of the world. Annual Meeting Proceedings include Chairman's Report, Working Group Reports and Papers Presented:

TABLE OF CONTENTS:

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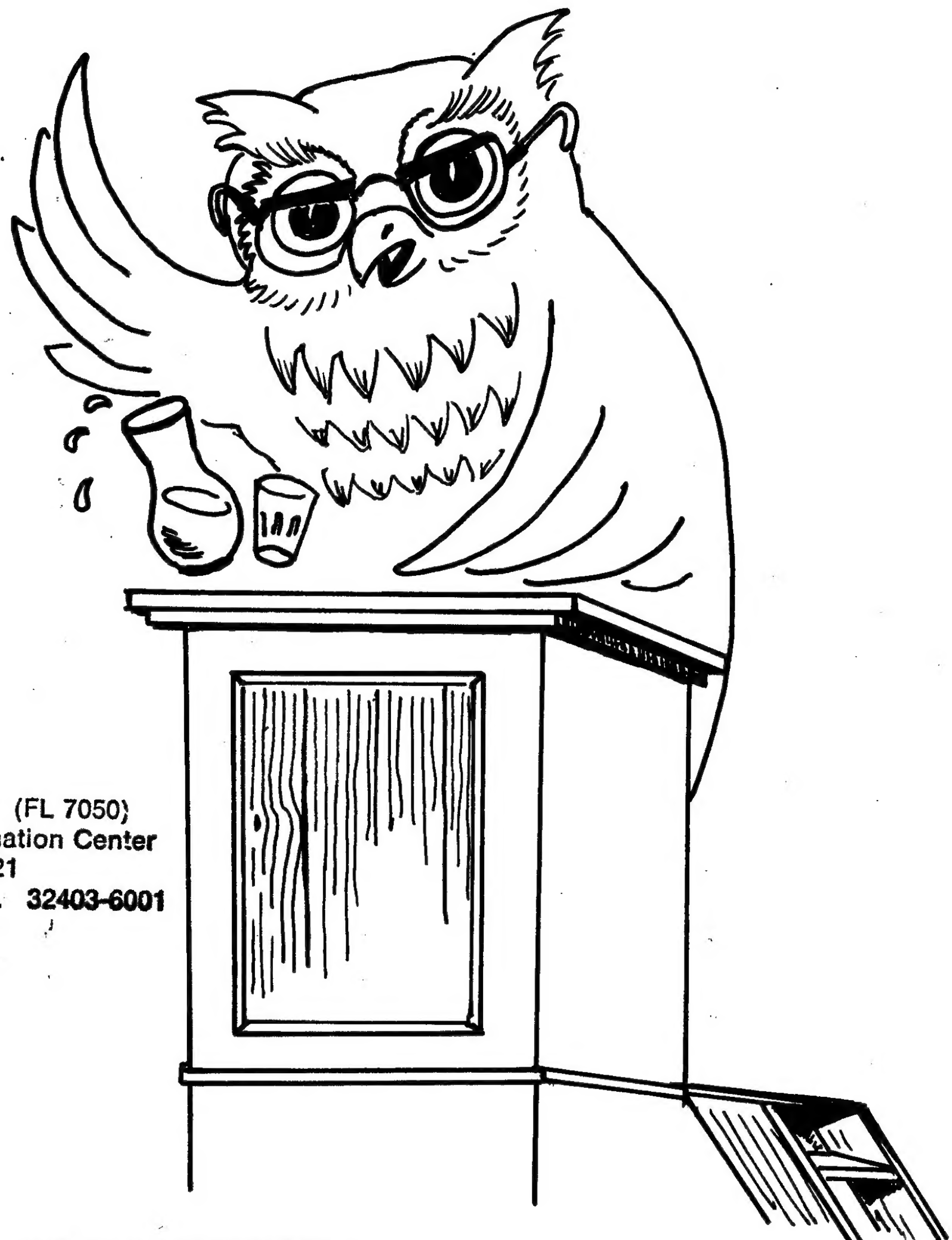
BIRD STRIKE COMMITTEE EUROPE

18th MEETING

COPENHAGEN, 26 - 30 MAY 1986



TO ALL PILOTS - WATCH OUT FOR BIRDS !!

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Bird Strike Committee Europe
Civil Aviation Administration
Aviation House
Ellebjergvej 50
DK-2450 Copenhagen SV
DENMARK

BSCE 18/WP 1
Copenhagen, January 1986

INVITATION

18TH MEETING BSCE

1. INVITATION:

The chairman of Bird Strike Committee cordially invites you to attend the 18th meeting of BSCE, which will be held in Copenhagen from 26th May 1986 and end on 30th May 1986.

2. LOCATION:

State apartment, conference room, entrance G,
cf. the enclosed appendices 1 and 2.

3. ADDRESS OF THE ORGANIZING COMMITTEE:

H. Dahl
Civil Aviation Administration
Aviation House
Ellebjergvej 50
DK-2450 København SV
DENMARK

4. AGENDA:

Registration of the participants will be held on 26th May 1986 between 08.30 and 10.00 local time.

The agenda is given below.

DATE	09.00-14.30 local time	14.30-18.30 local time
Monday 26th May	09.00: Steering Committee 10.00: Plenary 11.00 Analysis Work. Group 12.30-14.30: Lunch	14.30: Analysis Work. Group
Tuesday 27th May	09.00: Radar Work. Group 09.00: Com. Work. Group 10.00: Spec. Sub-group on Low-level Military Aircraft 12.30-14.30: Lunch	14.30: Struc. Test. Work. Group 14.30: Bird Movement Work. Group
Wednesday 28th May	09.00: Aerodrome Work. Group 12.30-14.30: Lunch	14.30: Aerodrome Work. Group 18.30: Reception in town hall
Thursday 29th May	09.00: Plenary meeting	Technical Visits
Friday 30th May	09.00: Plenary meeting	

5. THEMES FOR BSCE 18TH WILL BE AS FOLLOWS:

The various working groups, to which particularly specialists are invited to attend, will discuss the items assigned to them and which could be described as follows:

The Aerodrome Working Group shall study developped methods to control the presence of birds on or near aerodromes. Work has begun to collect material for 3rd edition of the booklet "Some Measures Used in Different Countries for Reduction of Bird Strike Risks Around the Airport". The Working Group Analysis has as main obligation to analyse the data on bird strikes. The Bird Movement Working Group should collect new data on bird concentration and bird migration with the view to revise the existing data and collect data on wildlife reserve sanctuaries and moist areas. The Working Group on Radar and Other Sensors should coordinate international collaboration in the field of radar research and bird migration as well as in the operational use of radar information for

bird strike prevention.

The Working Group on Communication and Flight Procedures should collect data encompassing methods used for transmission of bird hazard information and flight procedures and contemplate standardisation of such flight procedures for helicopters, light aircraft and military low-flying aircraft when possible.

The Structural Testing of Airframes Working Group should collect relevant information from the national organisations engaged in the production of the sign guidance material.

The Steering Committee has urged aircraft manufacturers to attend the meeting with the aim to present their views of the work to be done to withstand bird strikes, e.g. improve the design of engine and helicopter rotor blades.

According to a suggestion made within the Steering Committee is envisaged that an informal meeting be held on Tuesday following the meeting in the Communication Working Group and dealing with specifically military aviation problems such as low-level flights.

6. RECEPTION:

A reception will be held in the town hall of Copenhagen on Wednesday at 18.30 local time until 20.00 (informal dress).

There will be no special arranged transport to the reception but the bus lines 2 and 8 from the corner of Strandgade/Torvegade can be used for transportation.

7. TECHNICAL VISITS:

29th May.

8. LADIES' PROGRAM:

Will be announced later.

9. NOTIFICATION OF PARTICIPATION:

Participation in the meeting should be notified to the chairman by filling in the attached paper (Appendix 3) and preferably before 15th March.

10. WORKING PAPERS:

The Steering Committee has decided that BSCE will publish the working papers

received before 1st April 1986 in a bound set to be collected at the start of the meeting and that papers arriving after 1st April 1986 will be published together with a report of the discussions and recommendations in an addendum after the meeting.

The Steering Committee will decide if the working papers should be presented in the plenary or in the various working groups.

In order to obtain consistency of presentation the following shall be observed:

Type

Papers must be typed with a good quality black ribbon on A4 208 mm x 295 mm (8 1/4" x 11 1/2") paper with 20 mm margins on all sides.

It will be advantageous to draw a box 20 mm in from paper edge on all sides on a blank sheet of paper to use as a guide behind pages being typed or word processed. Due to problems with reproduction and readability, dot matrix printing is not acceptable. Print of type of 10 or 12 pitch is acceptable.

Format

Text should be single spaced with double spacing between paragraphs with text including new paragraphs being left margin justified.

Front Sheet

Each paper submitted should start with a front sheet which has at the top right hand BSCE 18/ then a space for the organisers to insert a Working Paper number. Immediately below this should be typed Copenhagen May 1986. In the top third of the page should be typed the papers title in capital letters and underneath it the authors name and affiliation in upper and lower case. Below this should be a brief summary of not more that 200 words.

The body of the paper should be started on a new sheet.

Headings

All section headings should be in capital letters and left justified, while sub-headings shall be upper and lower case and left justification.

Figures and Tables

All figures and tables should be titled across the top with "FIGURE" or "TABLE" in capital letters followed by the number. The title should follow on the same line in capital and lower case letters.

Page Numbers

Pages shall be numbered in light pencil at the bottom centre of each page. The organisers will renumber all pages when compiling the Proceedings.

11. HOTEL RESERVATION:

The hotel booking has to be done by the participants themselves. Due to the hotel situation in Copenhagen at the time of the year it is strongly recommended, that hotel booking takes place no later than 1st March. For information a booklet is attached.

Yours sincerely,

H. Dahl
Chairman

BSCE 18/WP 2
Copenhagen May 1986

ADF616042

BEHAVIOUR OF ARAMID EPOXY COMPOSITE STRUCTURES TO BIRD IMPACT

By : Mr. Jean BESSE Avions Marcel Dassault-Breguet Aviation
Mr. Armand FUERTES Centre d'Essais Aeronautique de Toulouse

SUMMARY

Considering the development in Aeronautics of Aramid epoxy (Kevlar) structures, the French STPA has sponsored in CEAT an experimental investigation to know the behaviour of these structures in a bird impact.

The program of the investigation has been presented in the 17th BSCE.

We recall this program, its development and the contribution of the French Aircraft manufacturers.

The results of normal impact are presented both for the Kevlar 49 and partially for the Kevlar 29.

The oblique impact tests, the experimental difficulties encountered and their solution are also shown.

Référence
DTM-6010/86

AVIONS MARCEL DASSAULT-BREGUET AVIATION
(JB/YC)

BEHAVIOUR OF ARAMID EPOXY COMPOSITE STRUCTURES TO BIRD IMPACT

1. INTRODUCTION

In Working Paper n°6 of the 17TH B.S.C.E. Meeting, we have presented the French experimental research program on the behaviour of aramid epoxy (Kevlar *) composite structures exposed to bird impacts.

This program is sponsored by the French STPA in CEAT.
The Aircraft manufacturers : Dassault-Breguet Company (AMD-BA) and Aerospatiale Company (SNIAS) have contributed to this research by the supply of test specimens.

These specimens were in relation with the problems encountered in the certification of composite components for the following aircrafts :

FALCON 900	(AMD-BA)	Figure 1
ATR 42	(Aerospatiale)	Figure 2

Today's lecture will present and discuss the results of this experimental research over a two year period (October 1983 - December 1985).

At this date the program concerning the normal impacts is completed.

For the oblique impacts, the AMD-BA test specimens have required a large amount of work.

The delays for delivery of the CEAT rectangular plates (painted) and the test program of the CEAT gun, have deferred the performance of the systematic tests in oblique impact.

* DU PONT'S Registered Trade Mark

2. DEFINITION OF THE TEST SPECIMENS

The specimens described in Tables 1 and 2 have been built by CEAT (on the STPA program) and the specimens in Tables 3, 6, 7, 8 and 9 by the AMD-BA company.

The designation BZ310 concerns specimens of the STPA program.

The designation BZ410 represents the AMD-BA contribution to the fabrication of test specimens.

The specimens supplied by Aerospatiale are defined in Table 5.

- Table 1 and Figure 3 represent the CEAT monolithic plane plates
- Table 2 : CEAT plane plates sandwich, Figure 4 with one layer of honeycomb, Figure 5 with two layers.
- Table 3 : concerns the sandwich curved specimen with one layer of honeycomb material. These cylindrical specimens, having a small radius of curvature are representative of leading edges (Figure 6).
- Table 4 : defines the sandwich curved specimens with a great radius of curvature (Figure 7) representative of the skin of a radome.
- Table 5 and Figure 8 represent the Aerospatiale leading edges.
- Table 6 presents the AMD-BA specimens used to investigate the influence of the resin and for the first tests with Kevlar 29.
- Table 7 defines the AMD-BA monolithic plane specimens (arrangement of Fabric plies Figure 13).
- The AMD-BA sandwich plane specimens are represented in
  - Table 8 : specimens with impact surface painted
  - Table 9 : specimens with a thin sheet of 2024 aluminium alloy on the impact surface (Figure 9)
- Figure 10 represents a CEAT monolithic square plate modified by bonding of a 2024 plate at the top edge.
  This type of specimen has been used in the first oblique impact tests.
- Figures 11-12-13 show the arrangement of Fabric plies :
  - Figure 11 in sandwich specimens (one honeycomb layer)
  - Figure 12 in sandwich specimens (two honeycomb layers)
  - Figure 13 in monolithic plane plates

  The differences between the various arrangements also reflect the differences between the manufacturers concepts.
- Table 10 : gives the mechanical properties of the fabrics used.

3. TEST MEANS AND IMPACT CONDITIONS

Figure 14 is a general view of the test facility and pressurized air guns of CEAT. The 150mm diameter smooth bore gun only has been used.
The test specimens are supported by two frames :

- Figure 15 : for square plates in normal impacts
- Figure 16 : reclinable support for oblique impacts

Figure 33 : shows the test equipment at the nozzle of the gun, including, from right to left : the device for bird velocity measurement, the test specimen and the high speed camera (2500 frames/second).

The mass of the birds is 1.8 kg.

The birds are either freshly killed or frozen and thawed chickens.

Table 12 : gives the number of shots performed for each type of specimens.

4. RESULTS OBTAINED

4.0 Preliminary note

All results are expressed in terms of bird kinetic energy versus the number of fabric plies of the composite.

The kinetic energy integrates the variations of the bird masses. The relation between the mass of the unit area of the dry Kevlar plies and the number of plies is shown in Figure 30 (bottom curve).

4.1 Normal Impact

4.11 Kevlar 49

4.111 Kinetic energy of penetration

- Figure 17 gives the limit kinetic energy of penetration for the monolithic plane plates in Satin 8 and Figure 18 for the Satin 4. One will remark the proportionality of the kinetic energy of penetration to the number of fabric plies and the sensitivity to the arrangement of the fabric plies.

The Satin 8 style fabric absorbs more kinetic energy than the Satin 4 style. This property is due to the mode of weaving : the woven armor of a fabric of Satin 8 style is more deformable than that of a fabric of Satin 4 style.

- The time the resin impregnated fabrics staid in the workroom has led to the selection of epoxy-resin 145.5 (red) instead of the 145.2 resin (yellow).

- Figure 19 gives the results of tests performed on monolithic square plates (6 fabric plies).

The CEAT plates used as reference are assigned index "C".
The curing pressure seems to have some influence and the results with the resin 145.5 cured at 2.2 bars are about the same as those with the 145.2 resin cured at 3 bars.

- The impact tests on the sandwich specimens (Figures 20 and 21) have exhibited surprising characteristics to wit, for a small number of fabric plies, the strength of a sandwich specimen is equivalent to that of a monolithic specimen with less plies :

3+3 plies is equivalent to 4 plies monolithic
4+4 plies is equivalent to 7 plies monolithic

This particularity is more obvious on the Satin 8 fabrics. The presence of honeycomb layer(s) reduce the bird impact strength of the composite.

- Figure 22 shows all results obtained with the plane and curved specimens (monolithic and sandwich).

The level noted "K" indicates the strength of the Kevlar alone. The level noted "S" is that of the entire specimen.

4.112 Energy absorption after penetration

- Figure 23 (for the monolithic plane plates) and Figure 24 (for the sandwich specimens) show another disconcerting characteristic of the Kevlar structures :

Contrary to the metallic structures, the kinetic energy absorbed in the piercing of the plate is lower than the limit energy of penetration and this, one time out of two, by a large amount.

In these figures the ratio (W_a/W_p) of the absorbed energy to the limit energy of penetration, is indicated in terms of the ratio (W_o/W_p) of the initial bird kinetic energy (W_o) to the limit penetration energy (W_p).

The points are grouped along two straight lines :

(1) ...$(W_a/W_p) = 0.53$
(2) ...$(W_a/W_p) = 0.9 \quad (W_o/W_p)$

The characteristics of these lines are the failure pattern of the plate :

(1) corresponds to a star shape failure
(2) corresponds to a "paper leaf" shape (noted "book page")

Figure 25 shows these failures for the monolithic plates, Figures 26 and 27 for the sandwich plates.

These failure patterns are also found in the sandwich curved specimens (Figure 28) and in the Aerospatiale leading edges (Figure 29).
For the differents tests corresponding to these figures, Table 12 gives the quantities (W_o/W_p) and (W_a/W_p).

Today we have no satisfactory explanation for this phenomenon.

It seems that line (2) corresponds to the limit failures. For the results corresponding to line (1), it is difficult to incriminate the boundary conditions.

The vibration of the plate during the bird impact could provide an explanation for the plane specimens but the existence of this vibration cannot be foreseen. In addition this explanation does not seem to be suitable for the sandwich curved specimens.

The property described by line (1) is a drawback in the use of the material. Consequently the philosophy applicable to the use of such structure is either to contain a bird or to let the bird penetrate and to have underlying parts either suffeciently strong or protected by a metallic shield.

4.113 Comparison with 2024 Aluminium Alloy

As one can see the performance characteristics of these Kevlar structures, with regard to bird impact, are not remarkable. The comparison, at a same mass of unit area, with plates in 2024 aluminum alloy is given in Figures 30 and 31.

The columns in blue represent the bird kinetic energy limit of penetration of plates of equivalent thickness (middle curve of Figure 30).

For the thin plates the metal withstand twice the same energy as Kevlar. These results have been obtained on the same test support (Figure 15).

Figure 31 also gives the velocities used in the tests and the corresponding kinetic energy of the 1.8 kg birds.

4.12 Kevlar 29

The Kevlar 29 fabrics are used as shield against the solid projectiles (bullets). But the weavers do not have in their list of products fabrics of Satin 8 and Satin 4 styles.

For the direct comparison of performance between Kevlar 49 and Kevlar 29 in the case of bird impact, the BROCHIER company has had for this purpose to weave and impregnate with 145.2 resin two rolls of material each 100m long, the first one in Satin 8 style with filament yarns of 440 decitex, the second one in Satin 4 style with filament yarns of 1100 decitex.

The mechanical characteristics of these fabrics are given in Table 10.

The Kevlar 29 yarn costs less than the Kevlar 49 yarn. Consequently preliminary impact tests on Kevlar 29 plane plates have been quickly undertaken. AMD-BA company had built three specimens in Satin 8 (Designation Bz 459 A) and CEAT two specimens (Designation : 2467 for Satin 8 fabric and 2466 for Satin 4).

Figure 32 shows the test results and the comparison with Kevlar 49. The kinetic energy of penetration is about the same as that of Kevlar 49 but it seems that the absorbed energy after piercing is greater. We have also to point out that the permanent deformation of the plate resulting from the impact is, in the same conditions, more than twice that of Kevlar 49 plates.

Unfortunately, these first results did not fulfill the expected promises from the former tests with solid projectiles.

4.2 Oblique Impacts

4.21 Background : the problem encountered

If the absorption of the bird kinetic energy has been the unpleasant surprise of the normal impact tests, the shots with oblique incidence have showed another disconcerting property of the Kevlar plates. We have called this property : the sliding of the bird.

The first oblique impact tests have been performed on monolithic plane square plates mounted on the support shown in the right part of Figure 33.

The phenomenon appeared since the very first shots :

For an angle of incidence of 45° the kinetic energy of penetration is about the same as the one in normal impact.

Both the support and the length of the plate have been incriminated. Specimens, as shown in Figure 10, have been made and tested on the reclinable support shown at the left part of Figure 33.

The results were the same but when a sheet of Vacpack film is set on the surface, the component of the bird kinetic energy normal to the plate is at penetration equal to the energy of penetration in normal impact.

Figure 35 shows these first results in the form of normal kinetic energy of penetration versus the number of fabric plies. The coloured contour of the columns indicates the values of the limit penetration energy in normal impact.

Figure 36 represents the results of the tests with Vacpack film (index "V").

Note :

The Vacpack film is a material used to remove the composite pieces from the mould after curing.

The consequence of these first tests was that it was decided to paint the impact surface of the specimens like the aircraft skin.

The completion of the CEAT rectangular specimens was delayed and the corresponding oblique impact systematic tests deferred.

Meanwhile, for the design of the wing root fairings and of the nose of FALCON 900 aircraft, the AMD-BA company had to fabricate rectangular plane specimens, monolithic and sandwich, (see Tables 6,7,8,9) and also sandwich curved specimen (Table 4) which were the first to be fabricated. The tests performed on these specimens represent the major part of the oblique impact test campain.

4.22 Test Conditions

The tests were effected at high angles of incidence from 65 to 72° (grazing shots).

Velocity of 1,8 kg bird : 180 m/s

Bird kinetic energy : 29300 joules

The attachment of specimens to the support was, at first, peripheral (Figure 34). Then after the sandwich curved specimens had been eliminated due to their cost and also because they were too short, each curved specimen was replaced by two plane specimens.

These plane specimens have been tested in two different manners :

In the first one the specimen is attached in the high position (Figure 39) and fastened at the top and bottom.

In the second one the specimen is attached in the low position (Figure 40) so as to leave a gap between the upper edge of the specimen and the border of the support, to let the bird go through.

In this case the attachment is lateral only.

These tests with two modes of attachment represent the best compromise found to take into account the influence of the curvature of the actual aircraft parts.

Note : In Figures 39 and 40 the support has been set slightly more upright to take the photograph.

4.23 Test results

The painting of the impact surfaces either like the aircraft skin (C.9999 + PU 66) or with a paint incorporating Teflon (CELLOGLISS) has not solved the problem of the sliding of the bird.
Only those tests specimens with a 2024 sheet bonded to the impact surface (Figures 9, 39 and 40) have eliminated this problem.
Before giving the results we must say that in our opinion, the words "Sliding of the bird" account for the property of the target to be "locally deformable". But because of the the thickness of the support we have never been able to see this deformation.

The test results on monolithic plane plates have been grouped together with the preliminary tests in Figure 35.

Figure 41 shows the results on the sandwich specimens, both plane and curved. The honeycomb material is glass, designated as "G" or 5056 aluminum alloy, designated as "A". Specimens 23a and b include carbon fabric plies and the impact face of specimens 34a and b is made of five plies of aluminum wire fabric.

For each test the coloured columns give on the left the total bird kinetic energy and its component normal to the target, on the right the energy absorbed with its components, both tangent and perpendicular to the plate.

For specimens 20a, 20b, 23a and b, 34a and b, the left group of two columns refer to a test in the top and bottom attachment condition, the right group to a test in lateral attachment condition. In all these tests the bird had penetrated.

Specimen 11 after impact is shown in Figure 38. The failure at the upper part is due to the presence of the support (as in Figure 37) and indicates that the specimen is too short.

Figure 42 shows, with the same conventions as in the preceding figure, the energy absorption for the sandwich specimens with a 2024 aluminum alloy skin. The yellow index "C" indicates a bird containment or penetration limit. The blue index "C" indicates an absolute bird containment.

These show that specimens 32 and 29, respectively tested with top and bottom and with lateral attachments, are the only ones to have contained the bird (in the two test configurations).

But the material of the honeycomb core (5056 aluminum alloy) was not suitable for a nose cone on account of the lightning-strike hazard. Therefore a curved specimen (Figure 43) has been built of same composition as specimen 21. The influence of the curvature compensates for the light deficiency resulting from the association of .6mm thick sheet and glass reinforced polyester honeycomb.

Figure 44 shows the frames of the shot's picture and it can be seen that the bird glances off the skin.

It must be said that the applications of all these specimens have not been developped because the thermal coefficients of expansion of Kevlar (negative) and aluminum alloy (positive) are too different from each other.

5. CONCLUSION

The presentation of these results does not go without some disappointment or at least regrets because great hopes had been placed on Kevlar to withstand bird impacts.

The characteristics found concerning the energy absorption reduces the benefit of the use of this material.

On other hand we do not know the degree of generality of the results given. The scattering of specimens is pratically unknown.

The gun also is not a very faithful tool. The obtainment of the hoped velocity proceeds more from the art or the luck of the gunner than from pure and cold science. Thus the limit values can be tainted with some dubiousness.

In addition for the oblique impacts each specimen has been subjected to one shot only. One can reasonably wonder whether the results obtained are not a mere collection of peculiar cases.

The behaviour of the specimens as a locally deformable target, perhaps due to the thinness of the plates, will create experimental difficulties in the systematic oblique impact tests on the CEAT rectangular plane specimens, both in the test stage and in the analysis of test results.

Without excessive pessimism, one can fear that the outcome will be poor and therefore the use of these results in the design of a new structure will not make obsolete the performance of bird impact tests on actual specimen representative of the aircraft part.

However the experimental work achieved should be considered as giving useful data for the clarification of future problems.

T A B L E S

TABLE 1 - CEAT MONOLITHIC PLANE PLATES

NUMBER OF SPECIMENS

MATERIAL		KEVLAR (R)49				KEVLAR (R) 29	
FABRIC		SATIN 8		SATIN 4		SATIN 8	SATIN 4
STYLE		DU PONT 181 NL-5.2233		DU PONT 285 NL-5.2234			
BROCHIER DESIGNATION		788		914		E 24.78 (SPECIAL	E 24.77 WEAVING)
RESIN EPOXY		145.2 (54.5%)		145.2 (54%)		145.2 (54.5%)	145.2 (54%)
SHAPE		SQUARE	RECT.	SQUARE	RECT.	SQUARE	SQUARE
NUMBER OF PLIES	6	5	4	4	2	6 (1 *)	6 (1 *)
	8	5	4	4	2	6	6
	12	4	4	4	2	6	6
	16	4	0	0	0	0	0

SIZES OF SPECIMENS : SQUARE = 475 X 475 (MM) RECTANGULAR = 475 X 700 (MM)

THE FACE OF IMPACT OF THE RECTANGULAR SPECIMENS IS PAINTED.

* : NUMBER OF SPECIMENS MADE AT 12-31-1985
(R) : DU PONT'S REGISTERED TRADE MARK

TABLE 2 - CEAT PLANE PLATES SANDWICH

MATERIAL : KEVLAR(R)49 EPOXY RESIN 145.2 (54%)

HONEYCOMB CORE : NOMEX(R) 3/16 4.5

NUMBER OF SPECIMENS

NUMBER OF HONEYCOMB LAYERS	1				2		
THICKNESS OF HONEYCOMB	7.5MM		20MM		T = 20MM EACH		
FABRIC	SATIN 8		SATIN 4		SATIN 4		
STYLE	DU PONT 181 NL-5.2233		DU PONT 285 NL-5.2234		DU PONT 285 NL-5.2234		
NUMBER OF PLIES	3+3	4+4	4+4	6+6	3+3+3	4+4+4	5+5+5
NUMBER OF SQUARE SPEC.	4	4	4	4	4	4	4
NUMBER OF RECT. SPEC.	2	2	2	2	0	0	0

SIZES OF SPECIMENS : SQUARE = 475 X 475 (MM) RECTANGULAR = 475 X 700 (MM)

THE FACE OF IMPACT OF THE RECTANGULAR SPECIMENS IS PAINTED.

(R) DU PONT'S REGISTERED TRADE MARK

TABLE 3

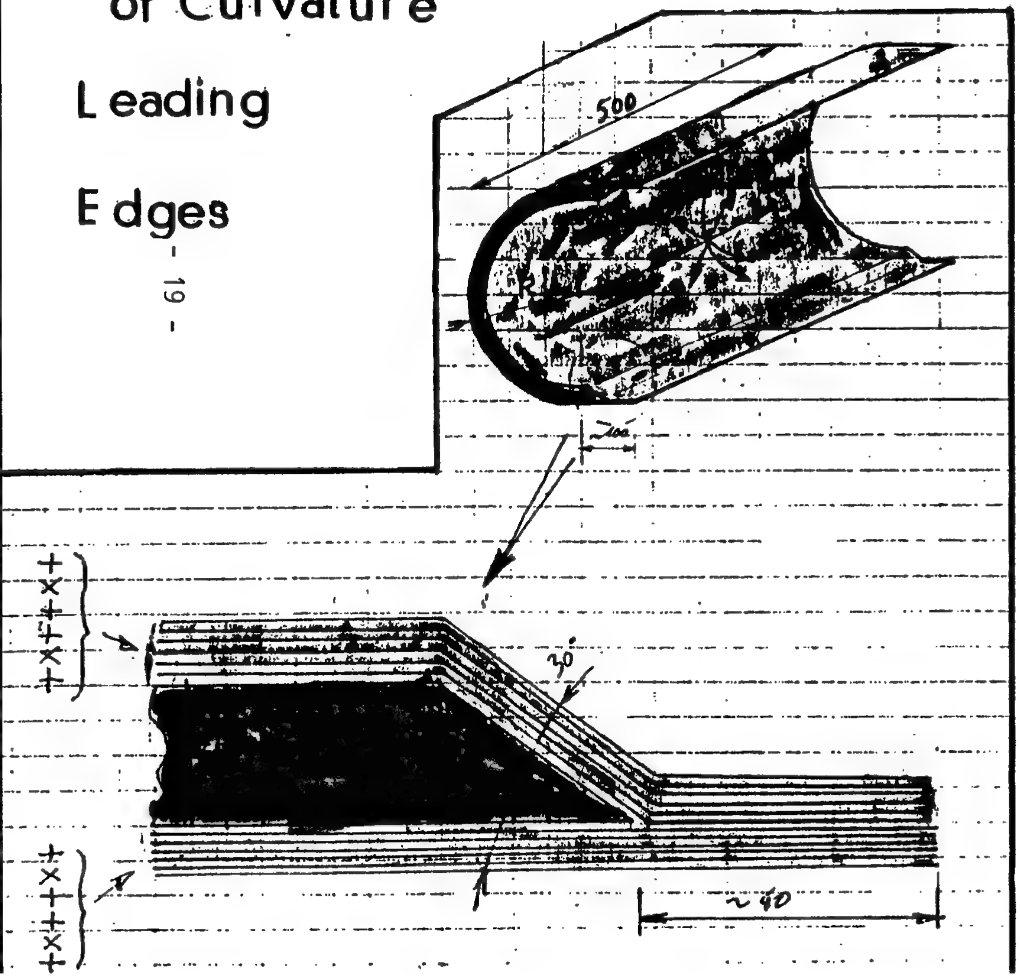
SANDWICH CURVED SPECIMENS (ONE LAYER OF HONEYCOMB)

FABRIC KEVLAR® 49 Satin 8 Ref 788 (Brochier Ind

RESIN Epoxy 1452 (54 %)

HONEYCOMB HEXCEL NYLON HRH 10 / F 505.0

Small Radius of Curvature Leading Edges



R (mm)	Number of Fabric Plies	AMD BA Designation
	NUMBER OF SPECIMENS	
	6+6	Bz 310 Rep
100	2	1
200	2	2
300	2	3

® Du Pont's REGISTERED TRADE MARK

TABLE 4 - AMD-BA SANDWICH CURVED SPECIMENS (ONE LAYER OF HONEYCOMB)

WIDE CURVATURE RADIUS R = 750MM

MATERIAL : KEVLAR(R)49

HONEYCOMB CORE : HEXCEL GLASS NP THICKNESS 7.7MM

AMD-BA DESIGNATION	BZ310 REP.1	BZ404 REP.11	BZ404 REP.14	BZ404 REP.15
HONEYCOMB	NP 3/16-6.0	NP 1/4-6.0	NP 1/4-6.0	NP 1/4-6.0
FABRIC	SATIN 8 NL-5.2233	SATIN 4 NL-5.2234	SATIN 8	SATIN 4
BROCHIER DESIGNATION	788	914	788	914
RESIN EPOXY	145.2 (54.%)	145.5 (54%)	145.5 (54 %)	145.5 (54%)
NUMBER OF KEVLAR PLIES	3+3	3+3	6+3	6+3
NUMBER OF SPECIMENS	2	2	2	2

ALL THE SPECIMENS ARE PAINTED ON THE IMPACT FACE.

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TABLE 5 - AEROSPATIALE LEADING EDGES

SANDWICH SPECIMENS WITH NOMEX(R) HONEYCOMB CORE

FABRIC KEVLAR®49 (SATIN 4) REF. A.S. PQ 10139.143.00

AEROSPATIALE DESIGNATION	1041	5006.15	SPECIMEN N° 2
NUMBER OF FABRIC PLIES	4+3+4	11+3	7+3+7
NUMBER OF HONEYCOMB LAYERS	2	1	2
THICKNESS OF EACH HONEYCOMB LAYER	20+20MM	20MM	15+15MM
MATERIAL DESIGNATION (HONEYCOMB)	NOMEX HRH 3/16 3.0		NOMEX 4.48

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TABLE 6 - AMD-BA MONOLITHIC PLANE SPECIMENS

SQUARE PLATES 475 x 475 (MM)

NUMBER OF FABRIC PLIES : 6

AMD-BA DESIGNATION	BZ404 24	BZ404 25	BZ404 26/26BIS	BZ404 27		BZ459 A
MATERIAL	KEVLAR(R)49					KEVLAR(R)29
FABRIC	SATIN 8	SATIN 8	SATIN 4	SATIN 8		SATIN 8
BROCHIER DESIGNATION	788	788	914	788		E24.78
RESIN EPOXY	145.2(54.%)	145.5 (54%)	145.5(54 %)	145.5 (54%)		145.2(54%)
CURING PRESSURE(BARS)	2.2	2.2	2.2	7		2.2
NUMBER OF SPECIMENS	2	2	4	2		3

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TABLE 7 - AMD-BA MONOLITHIC PLANE SPECIMENS

RECTANGULAR PLATES 600 x 900MM

MATERIAL KEVLAR(R)49 EPOXY RESIN 145.5 (54%)

AMD-BA DESIGNATION	BZ404 REP.13	BZ404 REP.18	BZ404 REP.19	DTM857/85 REP.18BIS	BZ404 REP.35	BZ404 REP.37
FABRIC	SATIN 4	SATIN 8	SATIN 4	SATIN 8	SATIN 8	SATIN 8
BROCHIER DESIGNATION	914	788	914	788	788	788
NUMBER OF FABRIC PLIES	6	6	6	6	16=11 IMPREGNATED +5 DRY	12=9 IMPREGNATED +3 DRY
ARRANGEMENT OF PLIES*	AMD-BA 1	AMD-BA 2	AMD-BA 2	CEAT	**	*CEAT*
NUMBER OF SPECIMENS	2	1	1	2	2	2

* FIGURE N° 13 INDICATES THE ARRANGEMENT OF PLIES

ALL THE SPECIMENS ARE PAINTED ON THE IMPACT FACE

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TABLE 8 - AMD-BA SANDWICH PLANE SPECIMENS

WITH HONEYCOMB CORE (THICKNESS 7,7MM)

MATERIAL KEVLAR(R)49 SIZE OF PLATES 600x900MM

RESIN : EPOXY 145,5 (54%)

AMD-BA DESIGNATION	BZ404 REP.16	BZ404 REP.17	BZ404 REP.20A	BZ404 REP.20B	BZ404 REP.23A	BZ404 REP.23B	BZ404 REP.34
FABRIC / BROCHIER	SATIN 8 (788)	SATIN 8 (788)	SATIN 8 (788)	SATIN 8 (788)	SATIN 8/788 CARBON/G803	SATIN 8/788 CARBON/G.803	SATIN 8/788 ALU:401 (145.5 60%)
NUMBER OF FABRIC PLIES	6+3	3+3	6+3	6+3	(3K+3C) +(3K+1C)	(3K+3C) +(3K+1C)	5, ALU + 6+3
ARRANGEMENT OF PLIES	AMD-BA	AMD-BA	AMD-BA	AMD-BA	AMD-BA*	AMD-BA*	CEAT
HONEYCOMB CORE HEXCEL REF	GLASS NP3/16 6.0	GLASS NP3/16 6.0	1/8-5056 .0015 6.1	1/8-5056 .0015 6.1	GLASS NP3/16 6.0	GLASS NP3/16 6.0	GLASS NP3/16 6.0
TOP COAT (PAINT)	C9999+PU66	C9999+PU66	C9999+PU66	CELLOGLISS	C9999+PU66	CELLOGLISS	CELLOGLISS
UPPER EDGING	HARDENING WITH BSL 204	HARDENING WITH BSL 204	HARDENING WITH BSL 204	HARDENING WITH BSL 204	HARDENING WITH BSL 204	HARDENING WITH BSL 204	27 LAYERS OF KEVLAR FABRIC(788)
NUMBER OF SPECIMENS	2	1	2	2	1	1	2

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TABLE 9 - AMD-BA SANDWICH PLANE SPECIMEN

WITH HONEYCOMB CORE THICKNESS 7,7MM AND 2024 + 351 SKIN

MATERIAL : KEVLAR 49(R) SATIN 8 (BROCHIER 788)

RESIN EPOXY 145-5 (54%)

AMD-BA DESIGNATION	BZ404 REP.21	BZ404 REP.22	BZ404 REP.32	BZ404 REP.29	BZ404 REP.30	BZ404 REP.33
NUMBER OF FABRIC PLIES	6+3	6+3	6+3	6+3	6+3	3+3
ARRANGEMENT OF PLIES	AMD-BA	AMD-BA	AMD-BA	CEAT	CEAT	AMD-BA
HONEYCOMB CORE HEXCEL REF.	GLASS NP3/16 6.0	1/8.5056 -.0015 6.1	1/8.5056 .0015 6.1	1/8.5056 .0015 6.1	GLASS NP3/16 6.0	GLASS NP3/16 6.0
THICKNESS OF THE SKIN	0.6MM	0.6MM	0.4MM	0.4MM	0.4MM	0.6MM
UPPER EDGING	HARDENING WITH BSL 204	HARDENING WITH BSL 204	HARDENING WITH BSL 204	27 LAYERS OF KEVLAR FABRIC 788	27 LAYERS OF KEVLAR FABRIC 788	27 LAYERS OF KEVLAR FABRIC 788
NUMBER OF SPECIMENS	4	3	1	1	2	2

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TABLE 10 - MECHANICAL CHARACTERISTICS OF THE FABRICS (TENSION)

Material		KEVLAR(R) 49							
Fabric Style		SATIN 8				SATIN 4			
Used in specimen		MONOLITHIC		SANDWICH		MONOLITHIC		SANDWICH	
Direction		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
CEAT Designation		2025K04	2026K04	2279K06	2281K06	2039K05	2028K05	2280K07	2282K07
Thickness (mm)		1,21	1,21	1,16	1,14	1,05	1,01	0,97	0,95
KVF (Volumic ratio of fiber)		0,378	0,376	0,390	0,396	0,459	0,478	0,498	0,509
Tensile strength Rr (MPa)	Gross	400	479	490	538	433	408	509	464
	Kevlar	1058	1274	1256	1358	943	854	1022	911
Tensile modulus E (MPa)	Gross	20400	24300	26100	28500	29100	28100	30500	31400
	Kevlar	53958	64628	66923	71969	63390	58787	61245	61689
$W = 0.5R_R^2/E$ (J/M^3)*	Gross	3,92 10^6	4,72 10^6	4,60 10^6	5,08 10^6	3,22 10^6	2,96 10^6	4,25 10^6	3,43 10^6
	Kevlar	10,37 10^6	12,56 10^6	11,78 10^6	12,8 10^6	7,019 10^6	6,20 10^6	8,53 10^6	6,74 10^6

* The tensile test curves are linear up to failure.

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TABLE 10 - MECHANICAL CHARACTERISTICS OF THE FABRICS (TENSION)

(Suite)

Material		KEVLAR(R)29			
Fabric Style		SATIN 8		SATIN 4	
Used in specimen		MONOLITHIC		MONOLITHIC	
Direction		Warp	Weft	Warp	Weft
CEAT Designation		2416K09	2417K09	2411K08	2412K08
Thickness (mm)		0,965	0,91	0,936	0,865
KVF (Volumic ratio of fiber)		0,472	0,502	0,487	0,527
Tensile strength Rr (MPa)	Gross	609	615	548	445
	Kevlar	1290	1225	1125	844
Tensile modulus E (MPa)	Gross	24600	25200	23400	20500
	Kevlar	52119	50199	48049	38900
$W = 0.5R_R^2/E$ (J/M^3)*	Gross	7,54 10^6	7,50 10^6	6,42 10^6	4,83 10^6
	Kevlar	10,37 10^6	12,56 10^6	11,78 10^6	12,8 10^6

* The tensile test curves are linear up to failure.

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TABLE 11 - NUMBER OF SHOTS

SHOOTING CONDITIONS	NORMAL IMPACT		OBLIQUE IMPACT	
DESIGNATION OF SPECIMEN	NUMBER OF SHOTS	SPECIMENS USED	NUMBER OF SHOTS	SPECIMENS USED
SQUARE PLATES MONOLITHIC	38	19/22	15	7
CEAT SANDWICH SQUARE PLATES(1 LAYER HONEYCOMB)	29	16/16		
CEAT SANDWICH SQUARE PLATES(2 LAYERS HONEYCOMB)	12	9/12		
SANDWICH CURVED SPECIMEN 1 LAYER HONEYCOMB(BZ3101-2-3)	7	6/6		
-IDEM- BZ310 REP.1 BZ404 REP.11-14-15	7	5/5	4	3/3
AEROSPATIALE LEADING EDGES	3	3		
AMD-BA SQUARE PLATES MONOLITHIC (KEVLAR 49)	20	10/10		
AMD-BA AND CEAT SQUARE PLATES MONOLITHIC(KEVLAR 29)	9	5/5		
AMD-BA RECTANGULAR PLATES MONOLITHIC BZ404 (TABLE 7)			9	9/10
AMD-BA SANDWICH PLANE PLATES BZ404 (TABLE 8)			10	10/11
AMD-BA SANDWICH PLANE PLATES WITH 2024 SKIN BZ404(TABLE 9)			12	12/13

TABLE 12

FAILURE PATTERN

W_O = INITIAL BIRD KINETIC ENERGY

W_P = BIRD KINETIC ENERGY OF PENETRATION (LIMIT)

W_A = KINETIC ENERGY ABSORBED

FAILURE PATTERN	STAR				BOOK PAGE			
SPECIMEN DESIGNATION	TEST NUMBER	FIGURE	W_O/W_P	W_A/W_P	TEST NUMBER	FIGURE	W_O/W_P	W_A/W_P
MONOLITHIC	37	25	1,135	0,527	40	25	1,068	0,868
SANDWICH ONE LAYER OF HONEYCOMB	54	26	1,468	0,641	68	26	1,082	0,908
SANDWICH TWO LAYERS OF HONEYCOMB	157	27	2,096	0,489	159	27	1,059	0,937
RADOME TYPE					100	28	1,007	0,895
RADOME TYPE					96	28	1,193	0,792
LEADING EDGE TYPE	90	29	1,202	0,519				
AEROSPATIALE LEADING EDGES.	93 94	29 29	1,882 1,673	0,464 0,524				

F I G U R E S

FIGURE 1

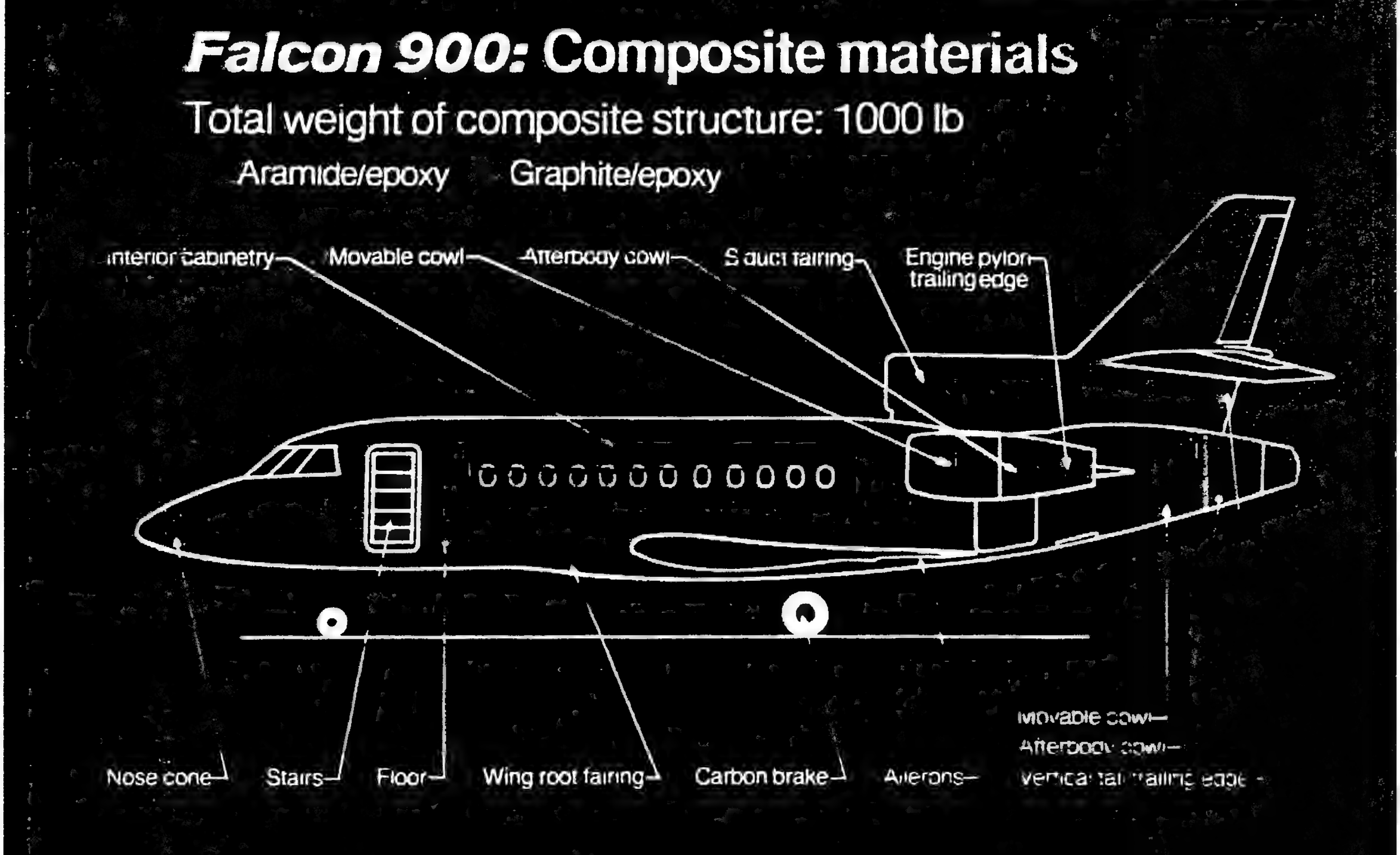


FIGURE 2

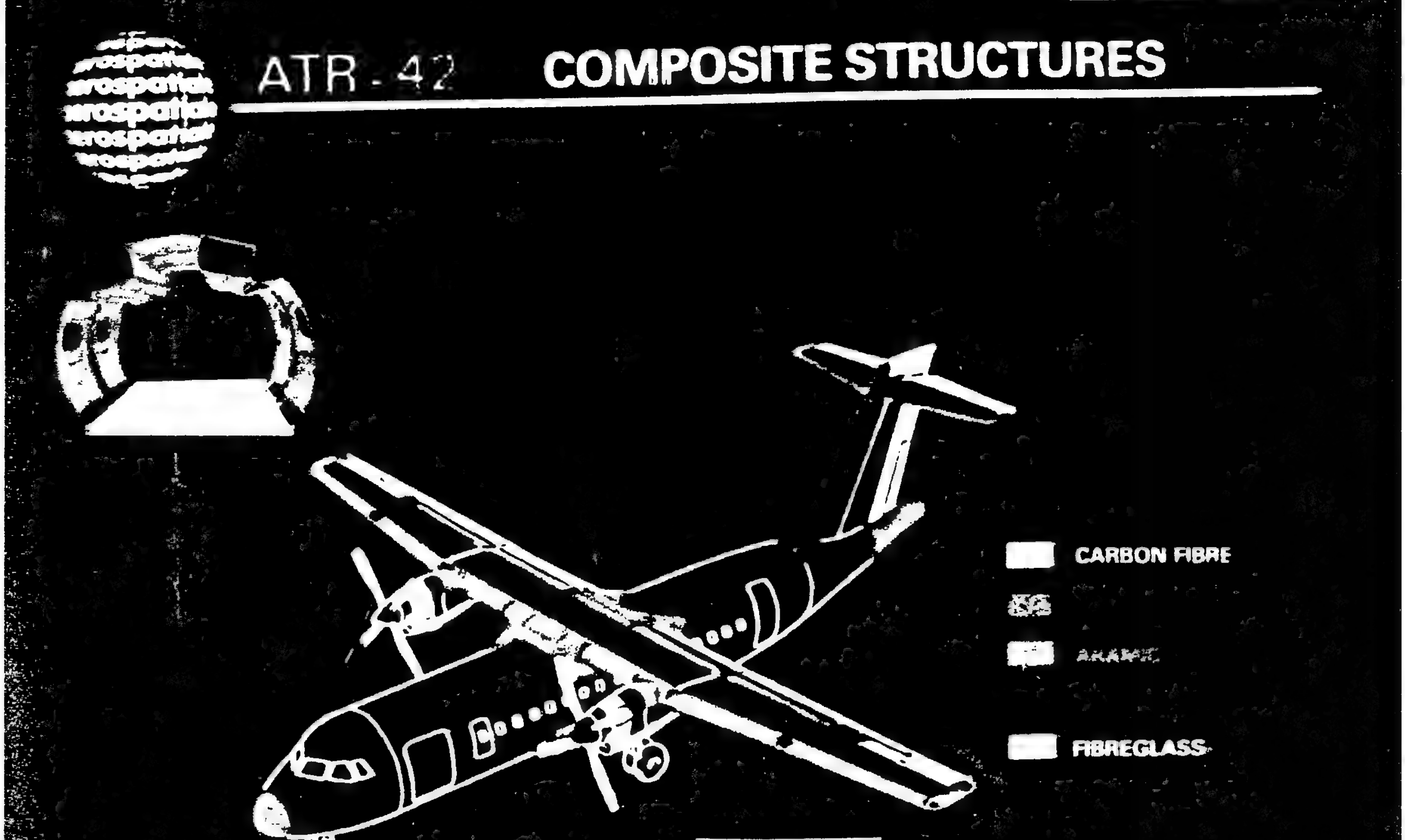
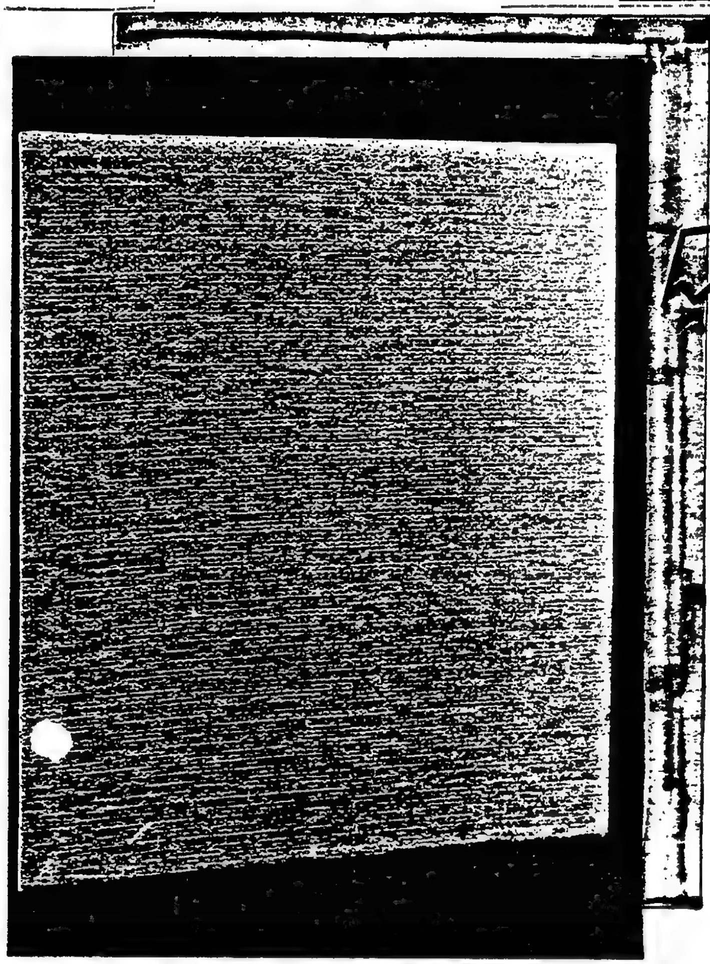


FIGURE 3



MONOLITHIC PLANE SPECIMEN

The arrow on the forward face indicates the direction of the warp of the first ply of fabric

FIGURE 4

SANDWICH PLANE SPECIMEN

One layer of honeycomb

THICKNESS OF THE HONEYCOMB CORE

t = 7,5 mm

t = 20 mm

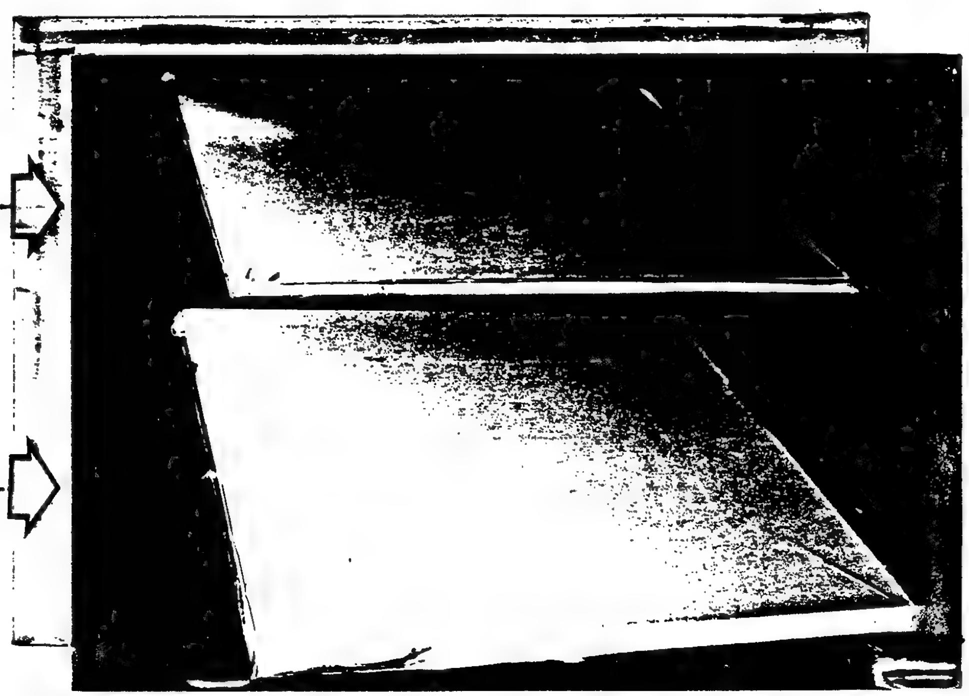


FIGURE 5

CEAT PLANE PLATES SANDWICH

WITH TWO LAYERS OF NOMEX® HONEYCOMB CORE

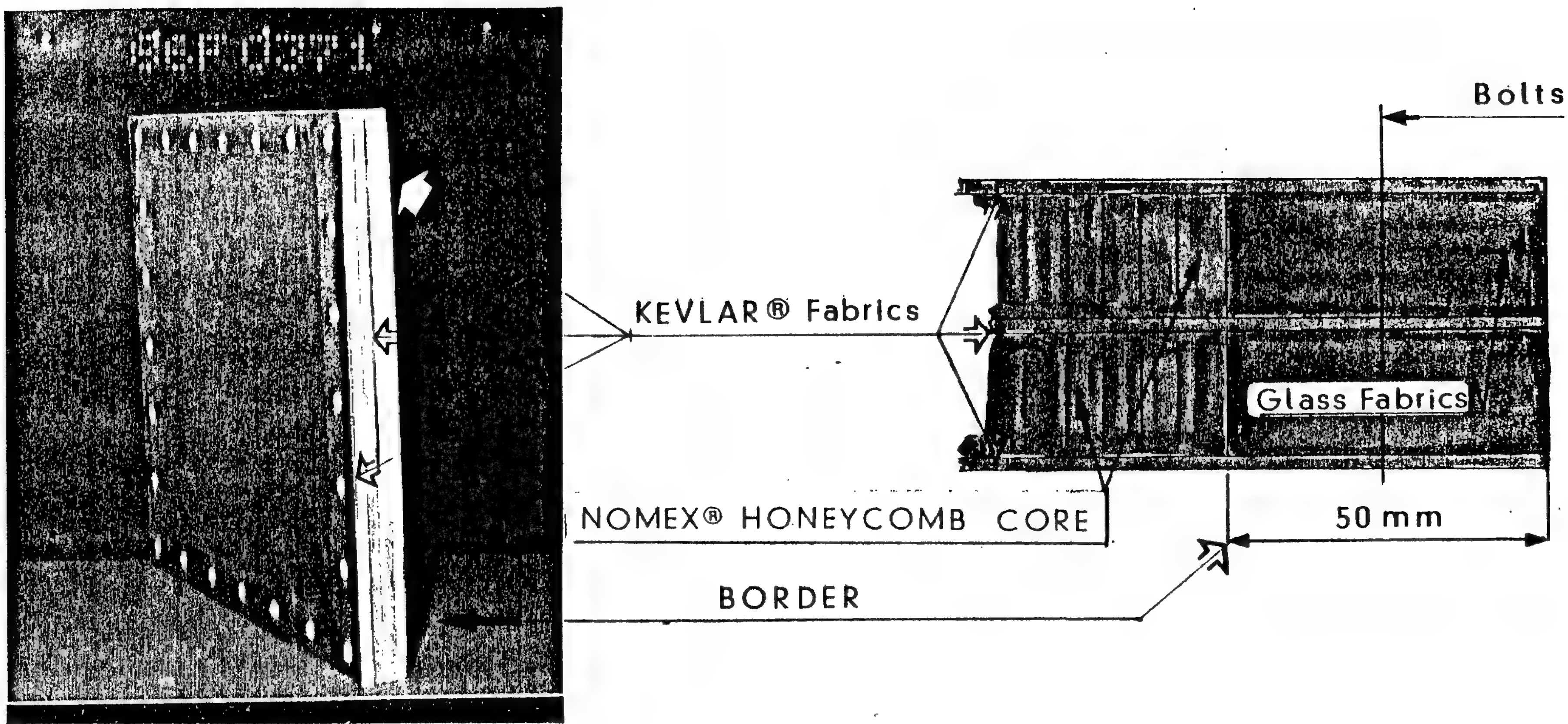


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FIGURE 6

SANDWICH CURVED SPECIMEN

One layer of honeycomb

Representative of the leading edges

SMALL RADIUS

OF CURVATURE

R = 100 mm

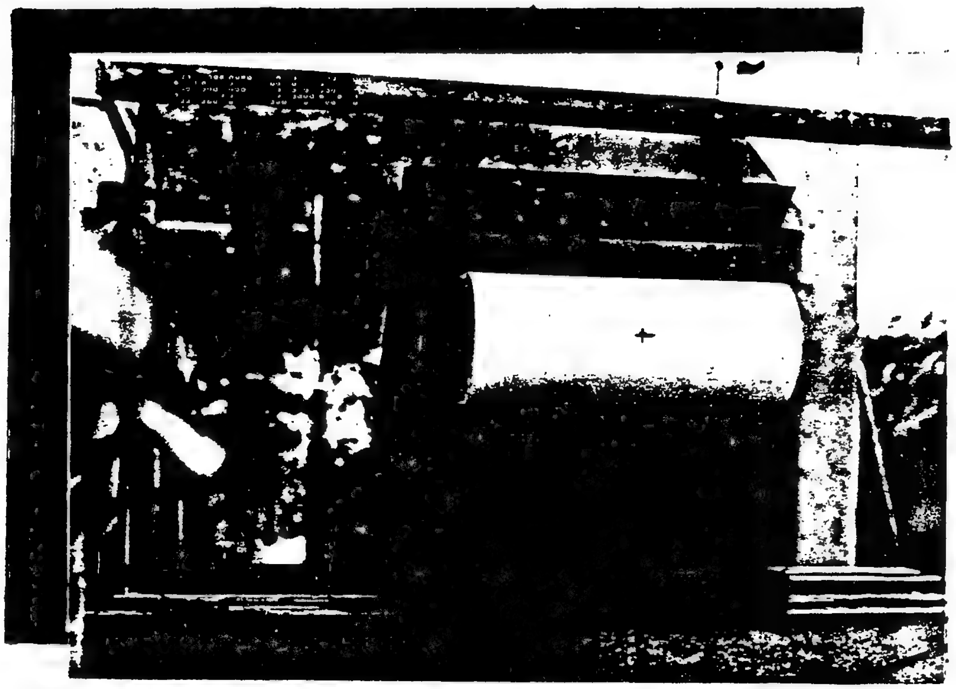


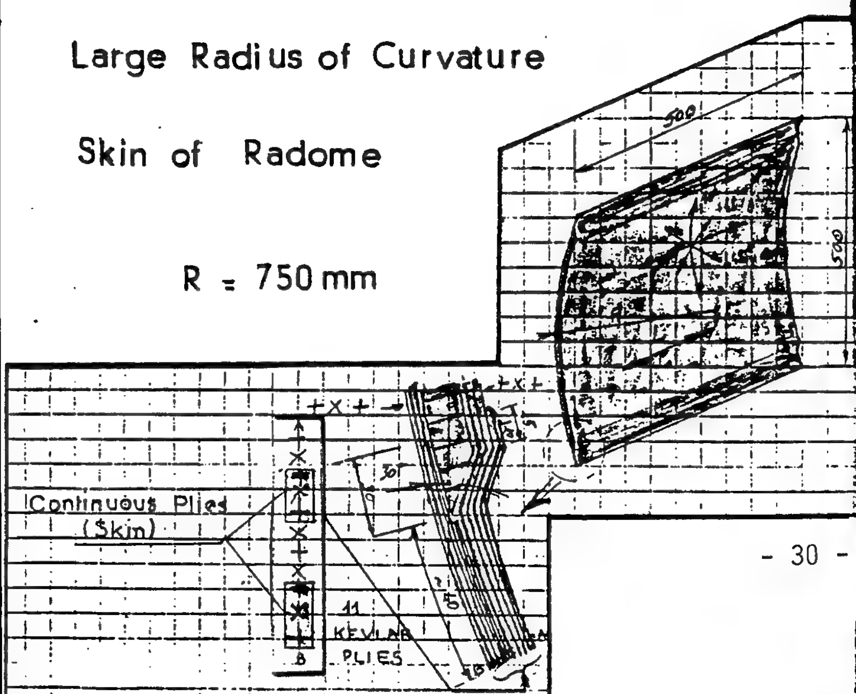
FIGURE 7

SANDWICH CURVED SPECIMENS (ONE LAYER OF HONEYCOMB)

Large Radius of Curvature

Skin of Radome

R = 750 mm



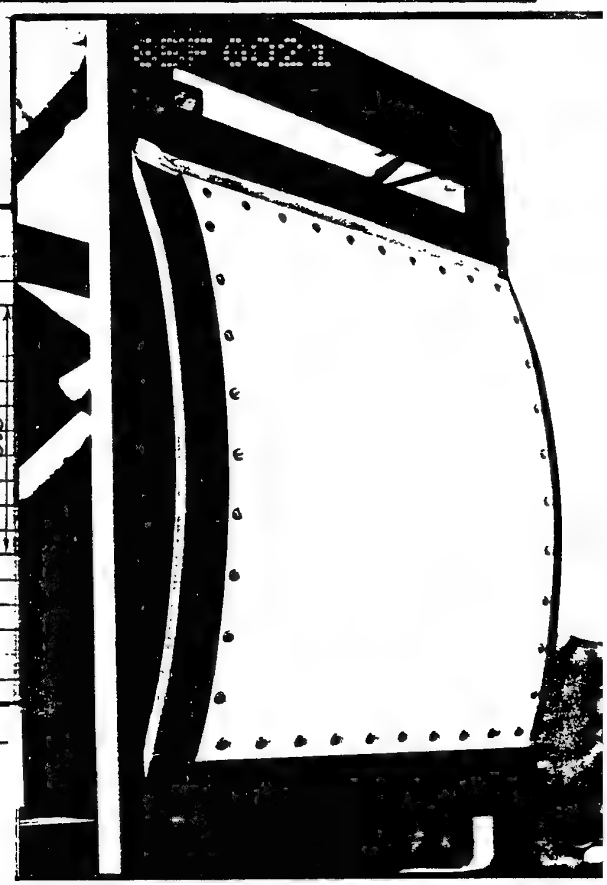


FIGURE 8

AEROSPATIALE LEADING EDGES

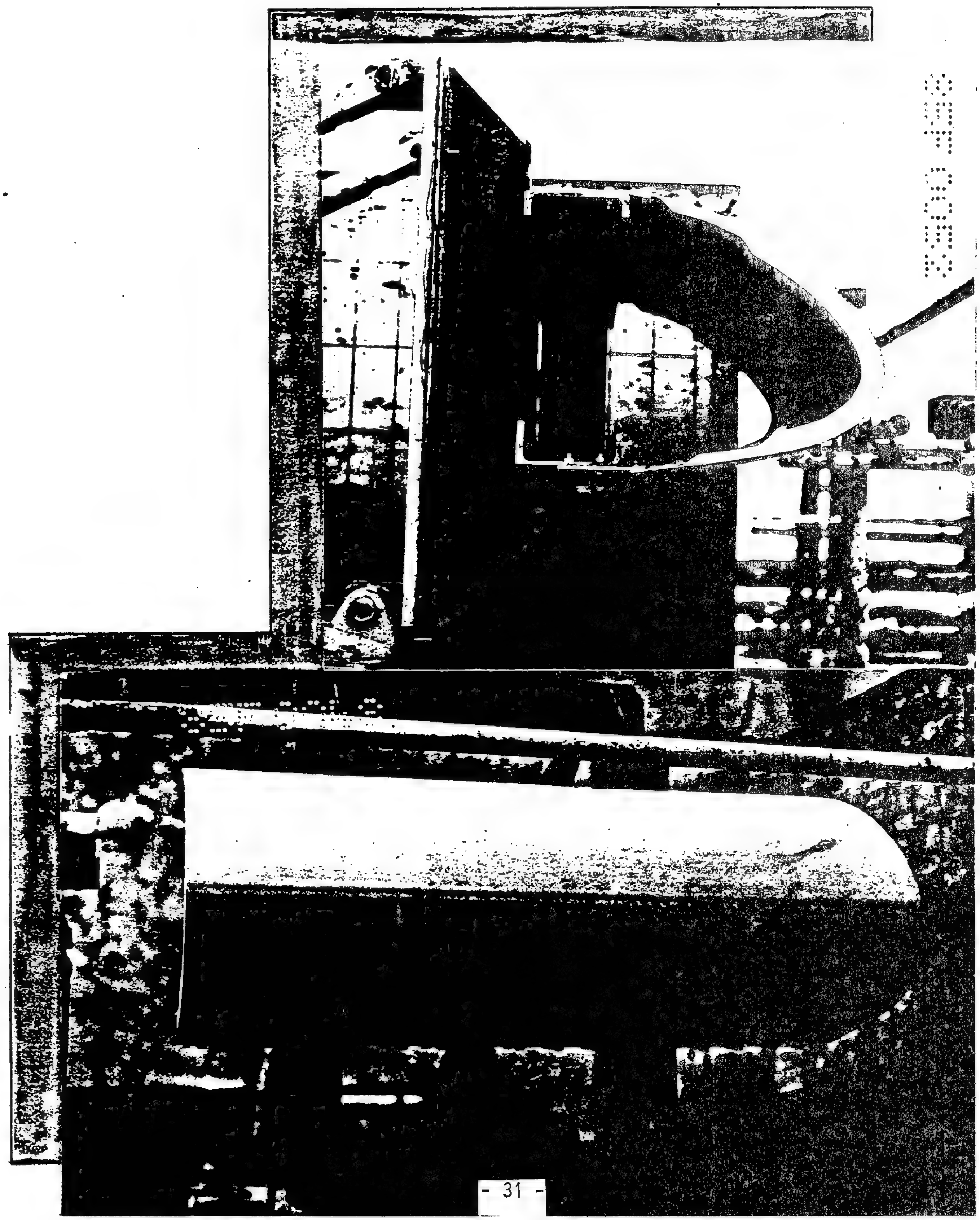


FIGURE 9

AMD-BA PLANE PLATES SANDWICH

WITH 2024 SKIN

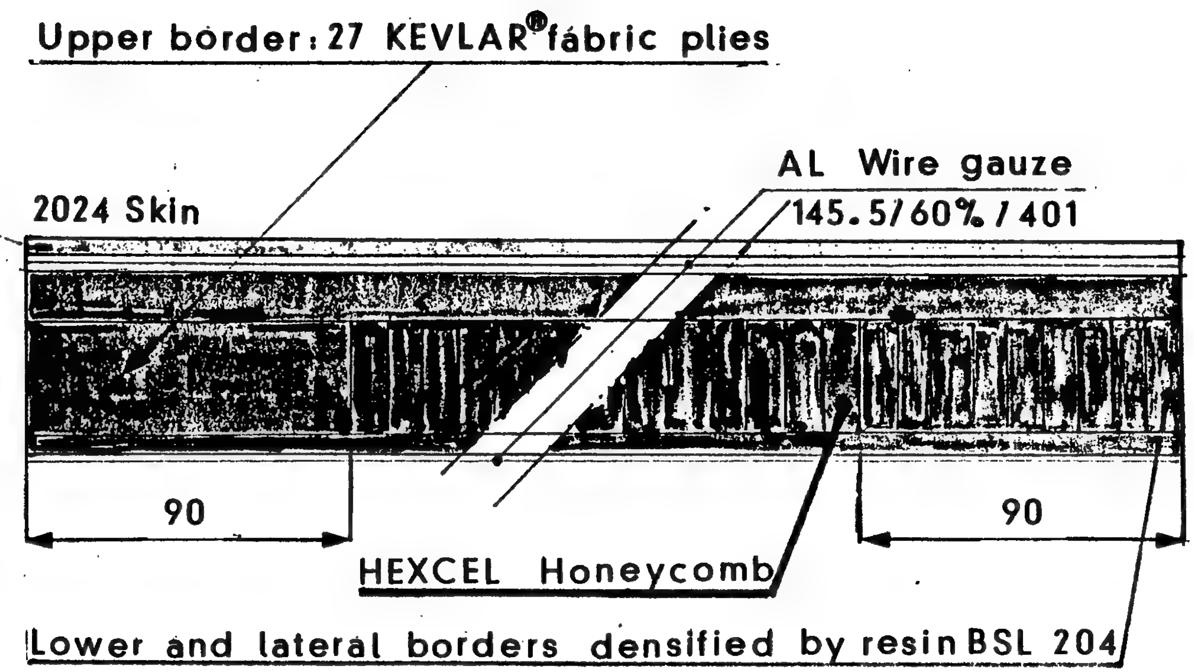
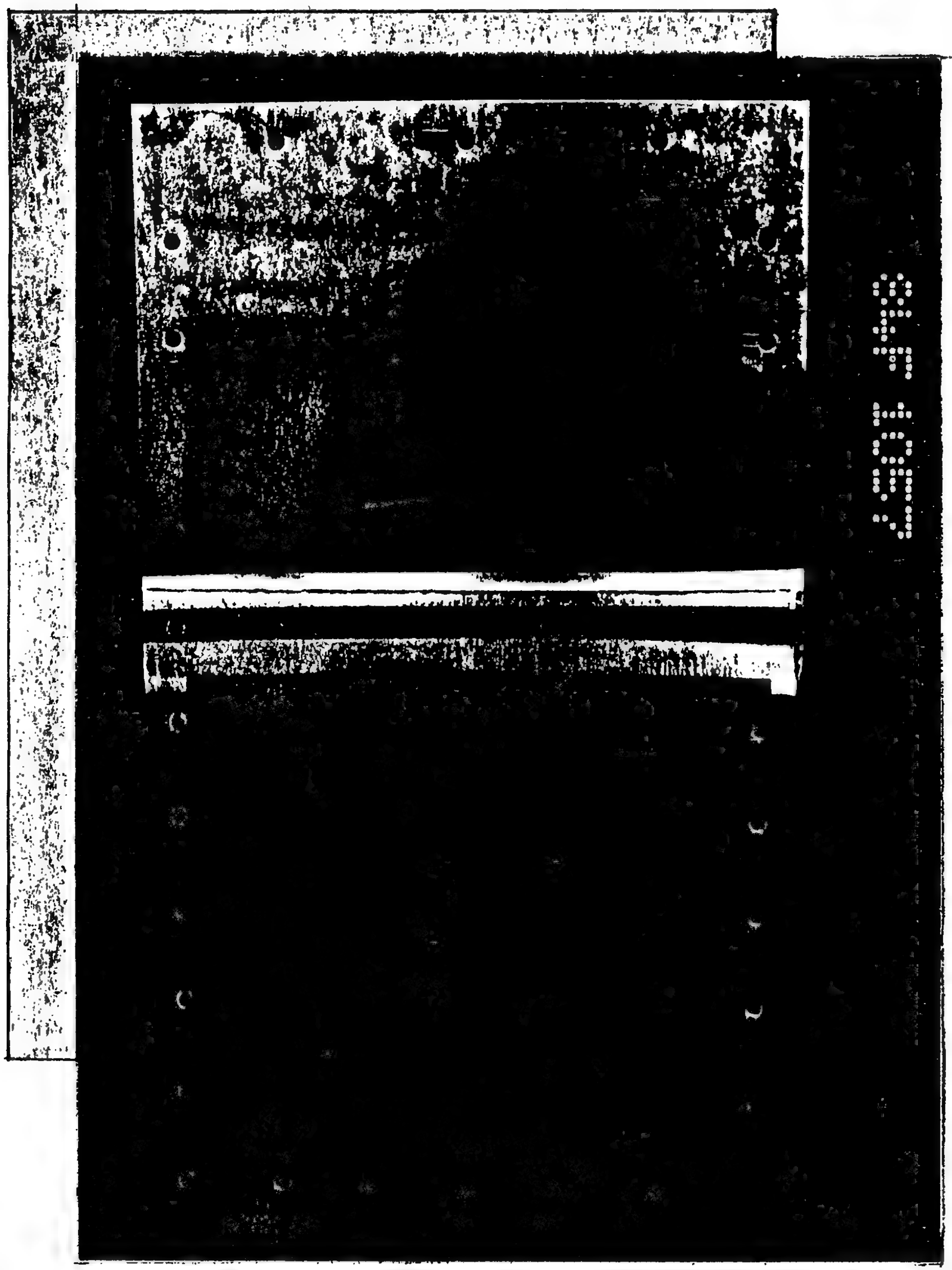


FIGURE 10

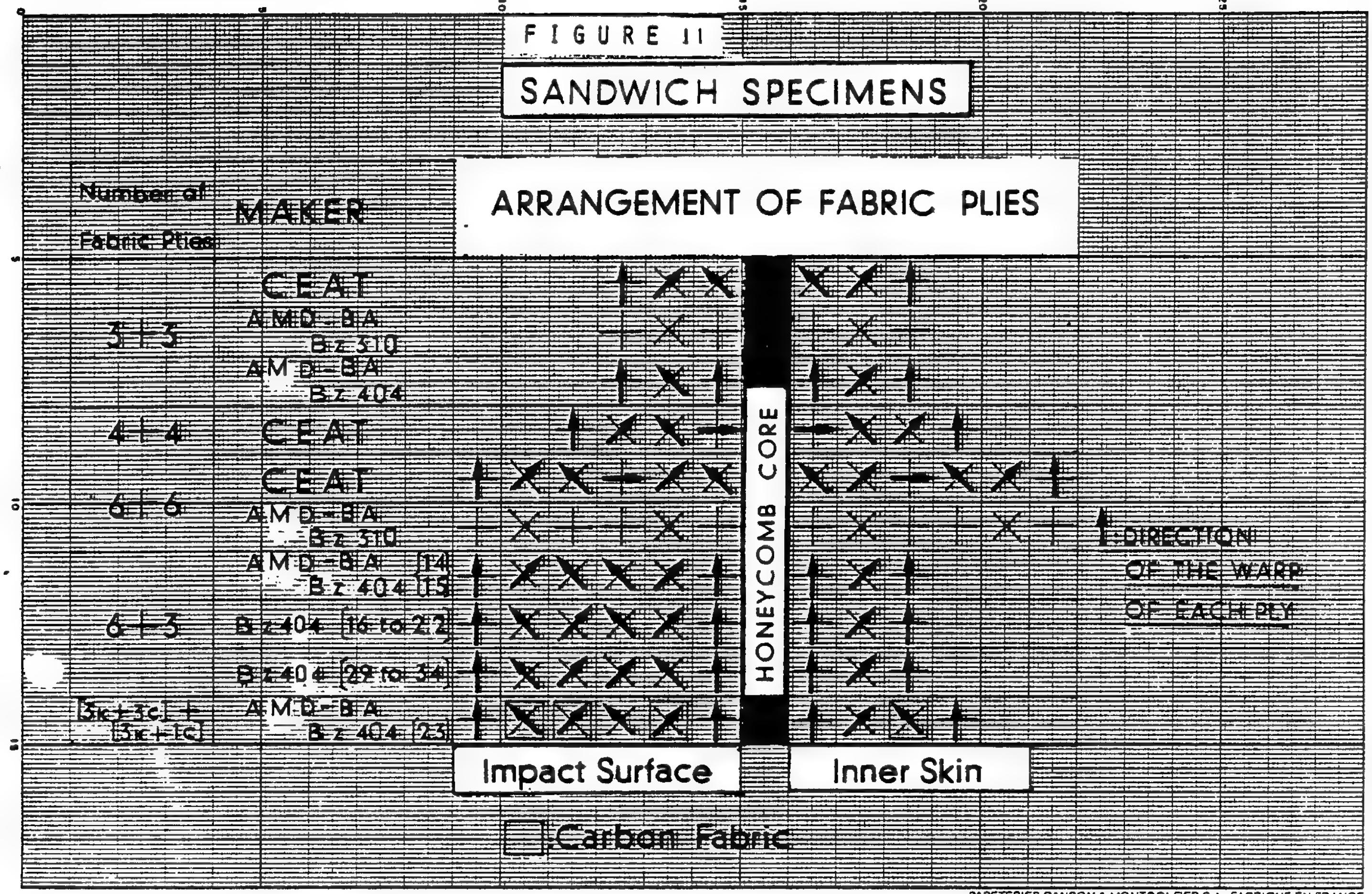


CEAT

MONOLITHIC PLANE PLATES

Specimen Modification
For Oblique Impact

Bonding of a Duralumin sheet at the top edge of the composite plate.



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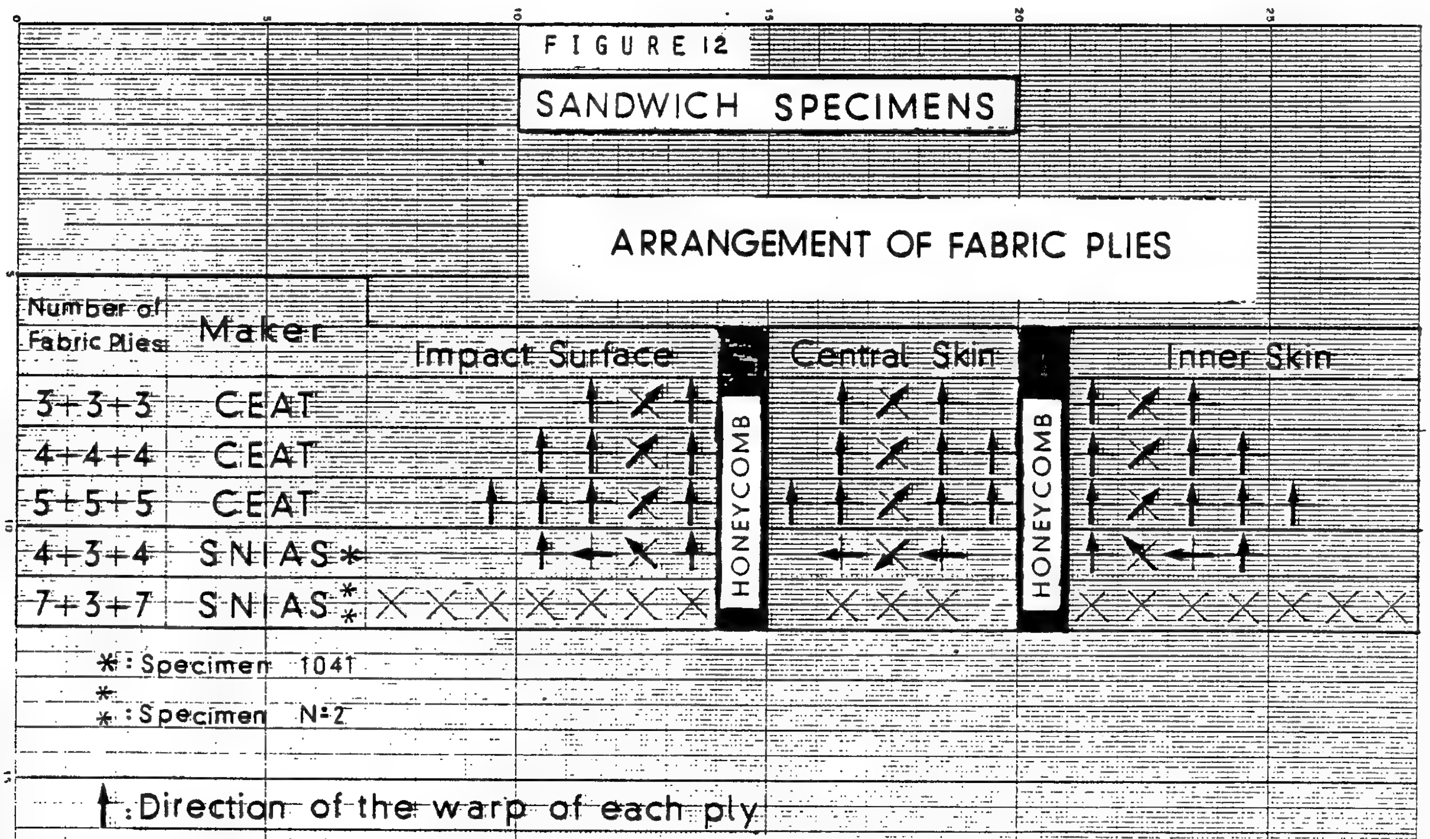

FIGURE 13

MONOLITHIC PLANE PLATES

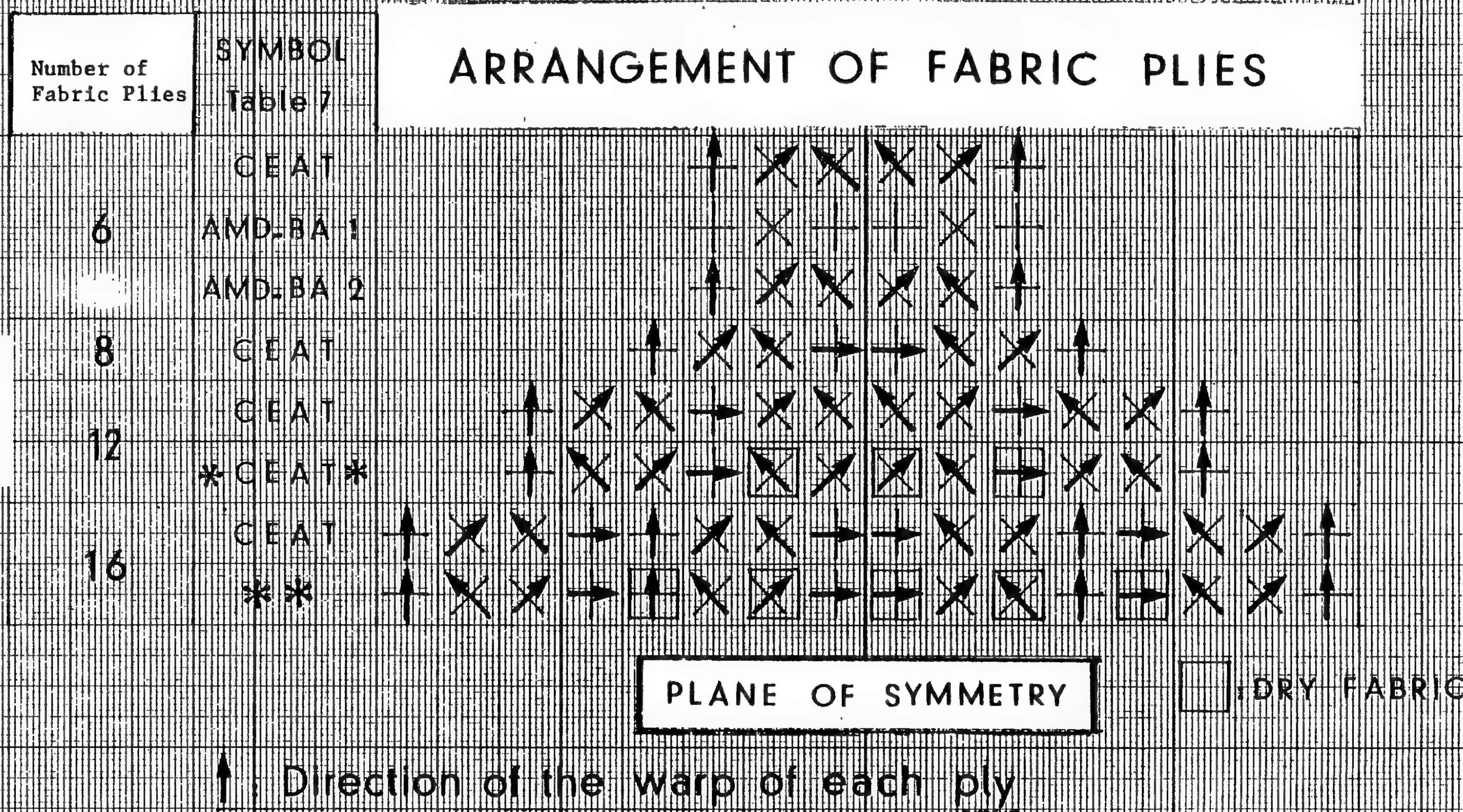

FIGURE 14

CEAT IMPACT TEST FACILITY

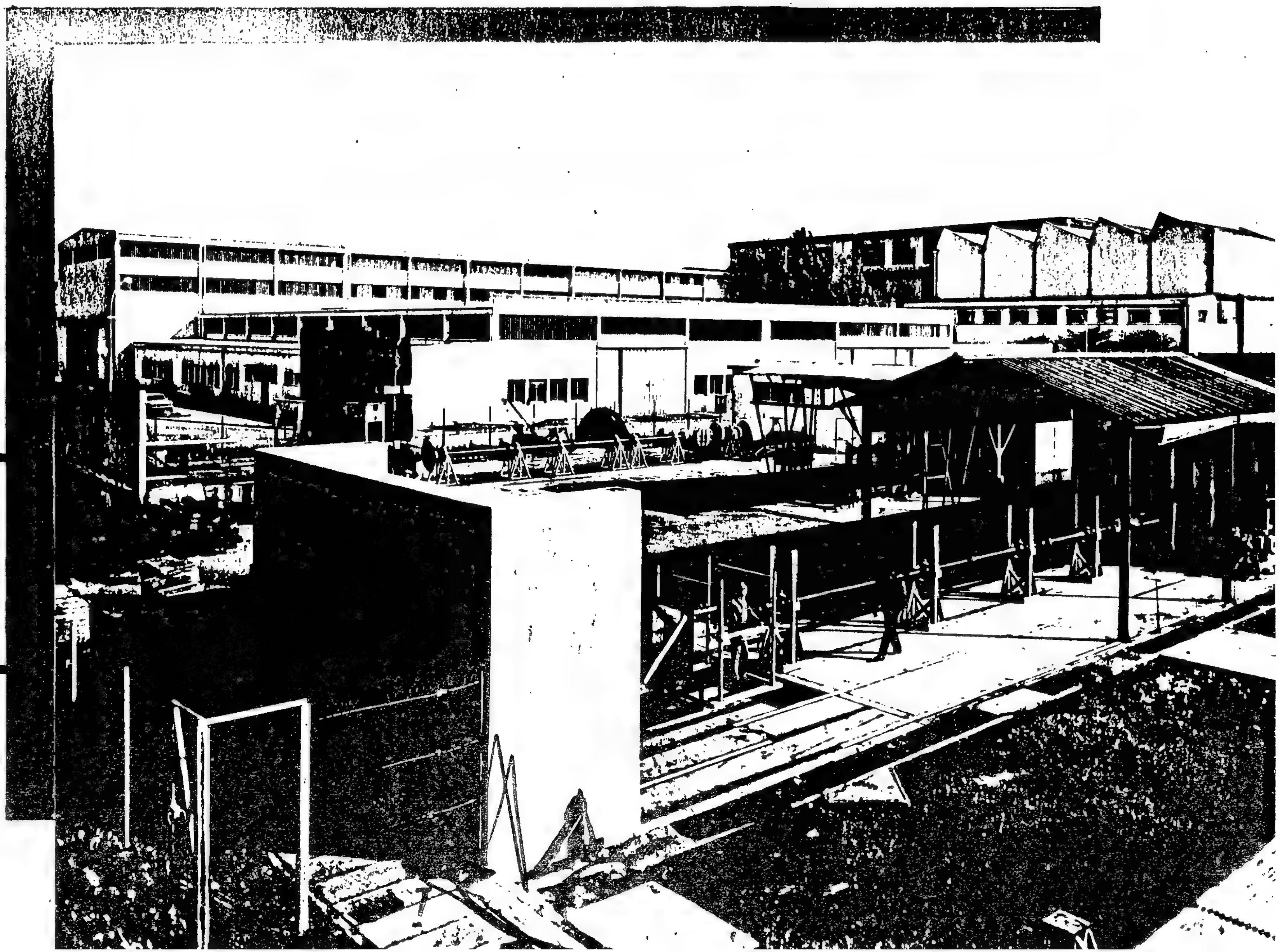

FIGURE 15

FRAME FOR SQUARE PLATES

IN NORMAL IMPACT

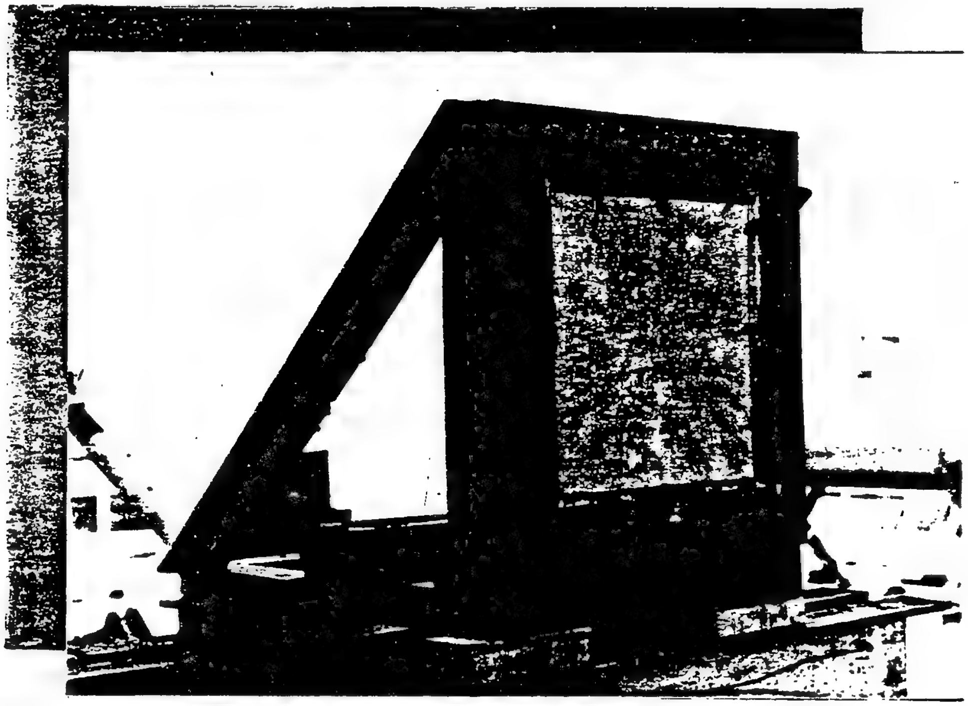

FIGURE 16

INCLINABLE SUPPORT

FOR OBLIQUE IMPACTS

FIGURE 17

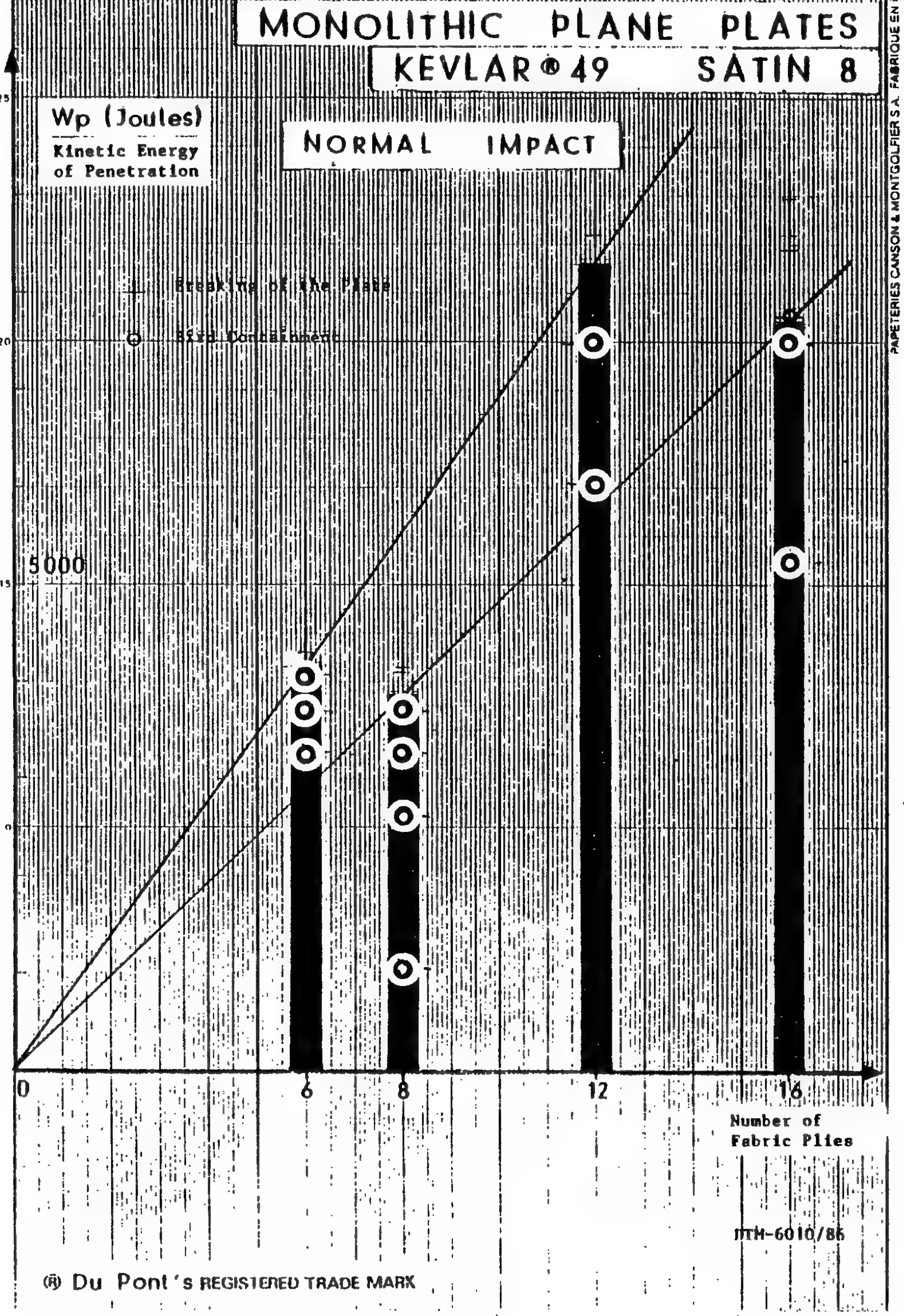

FIGURE 18

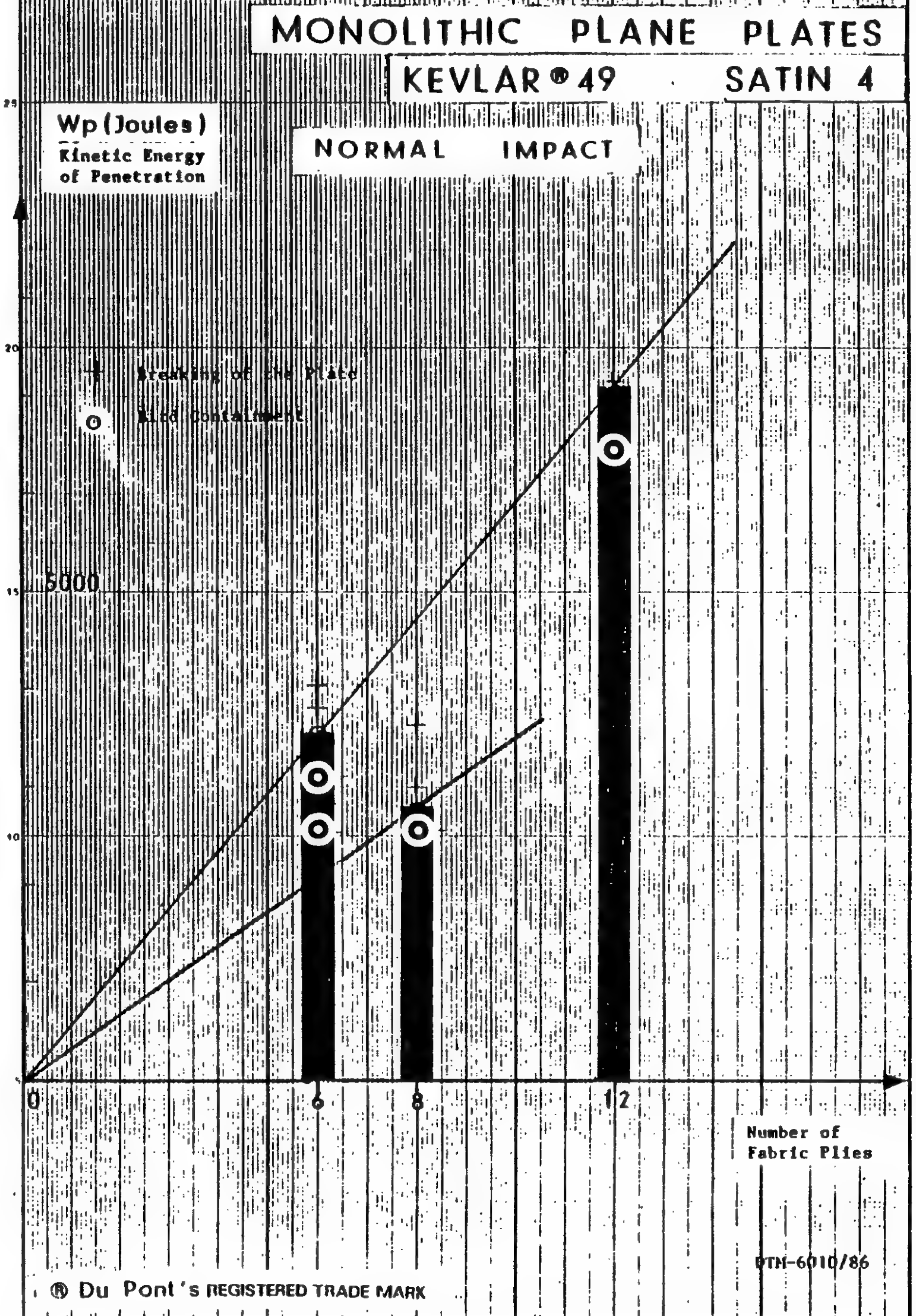

FIGURE 19

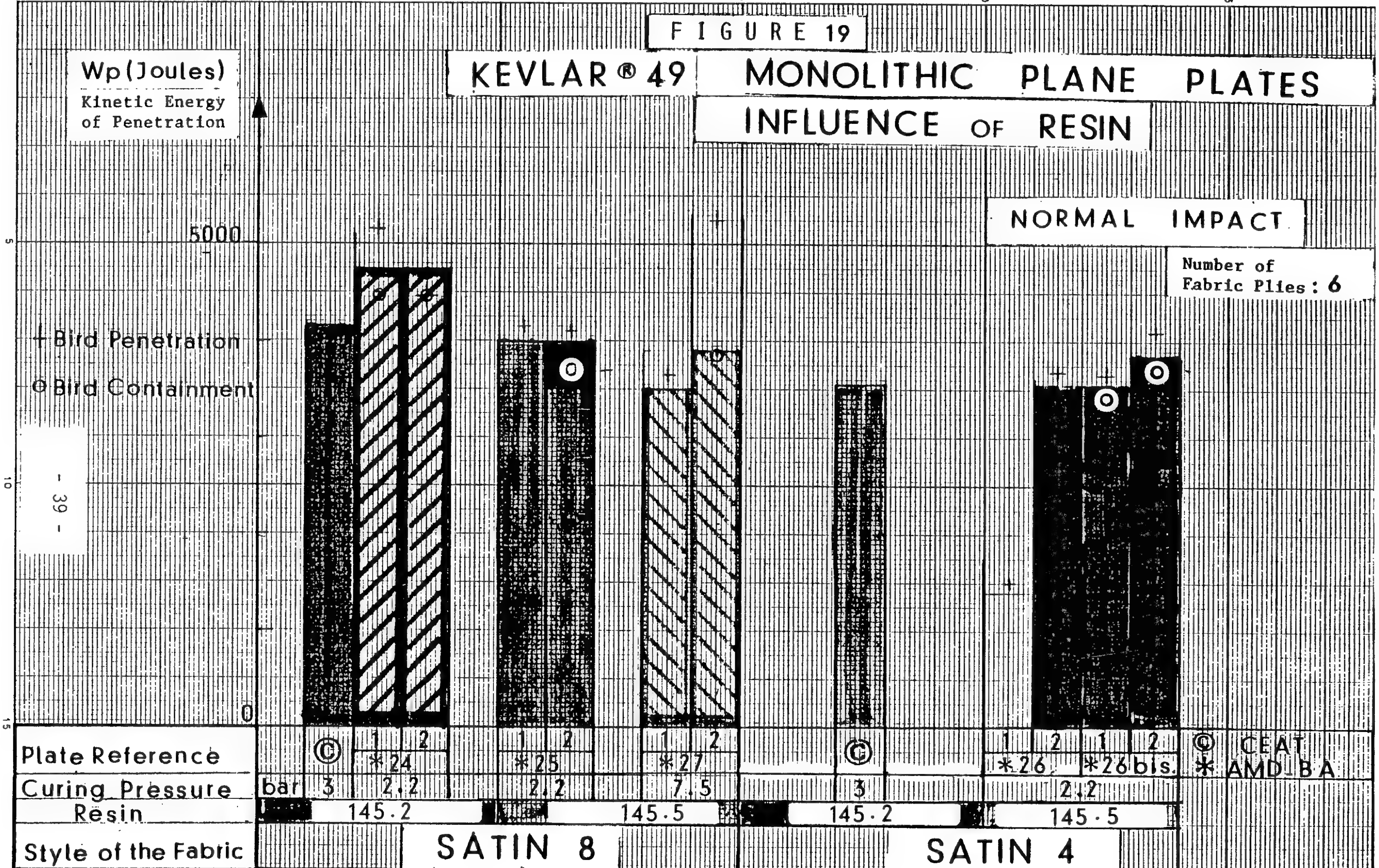

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FIGURE 20

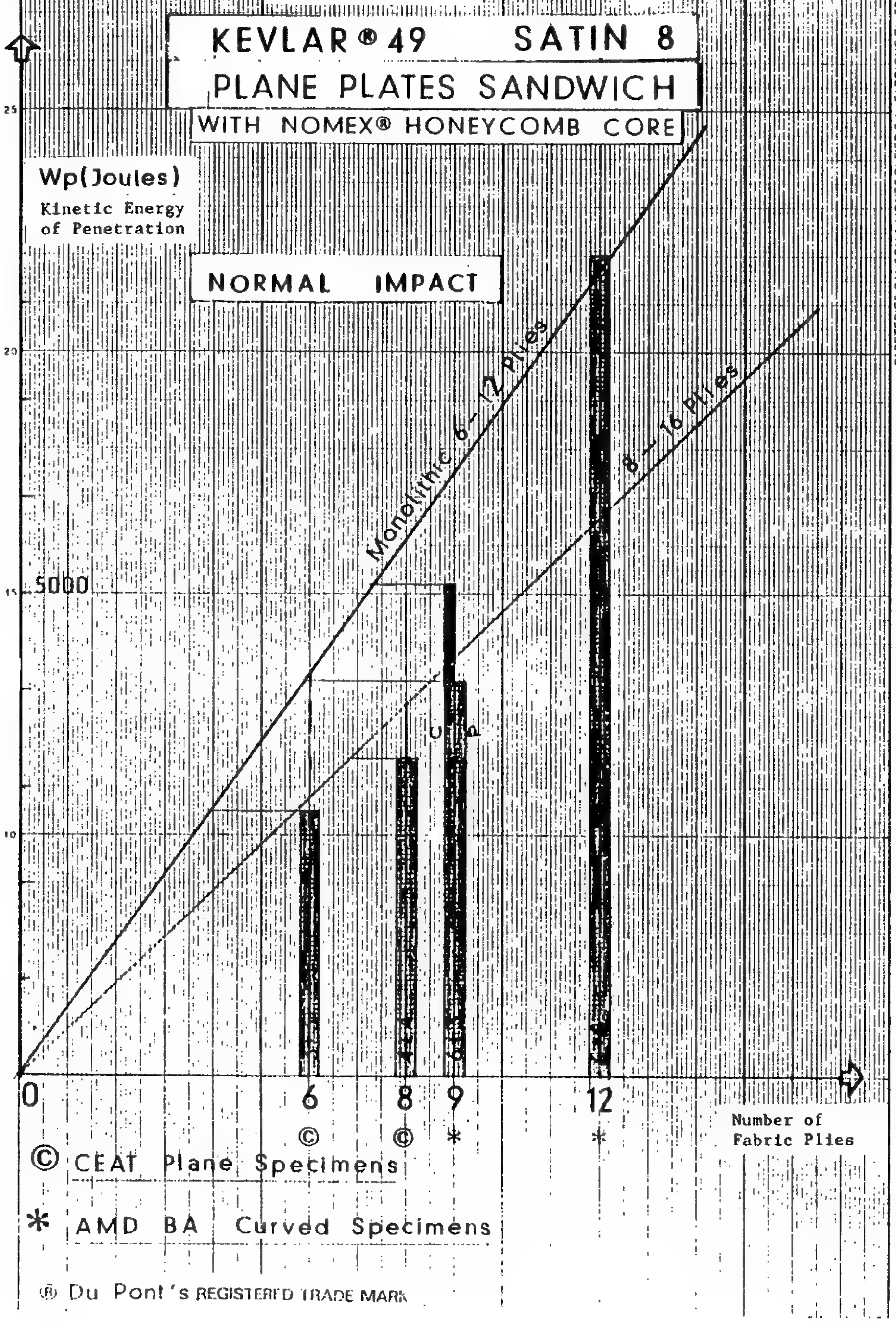


FIGURE 21

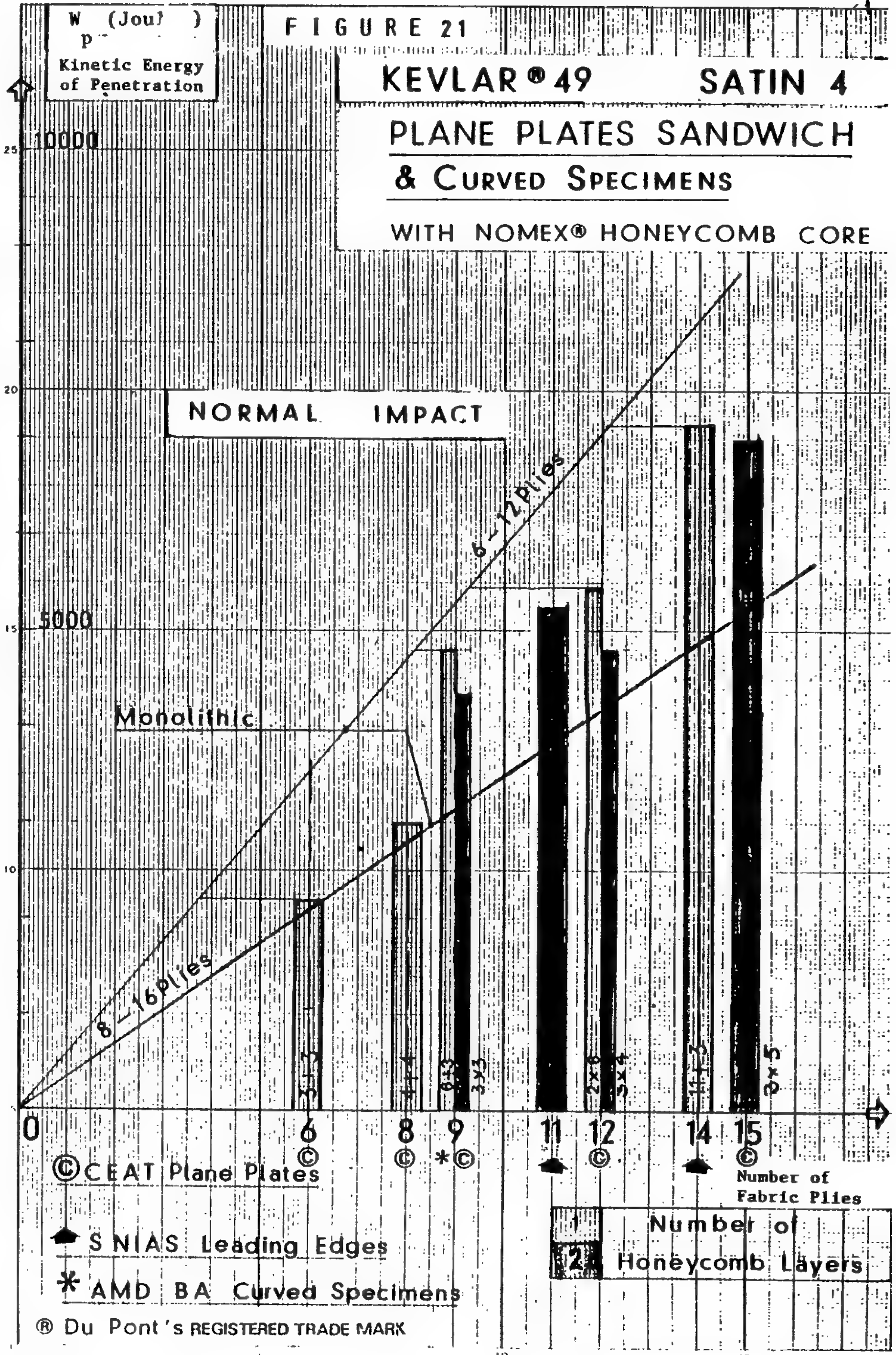
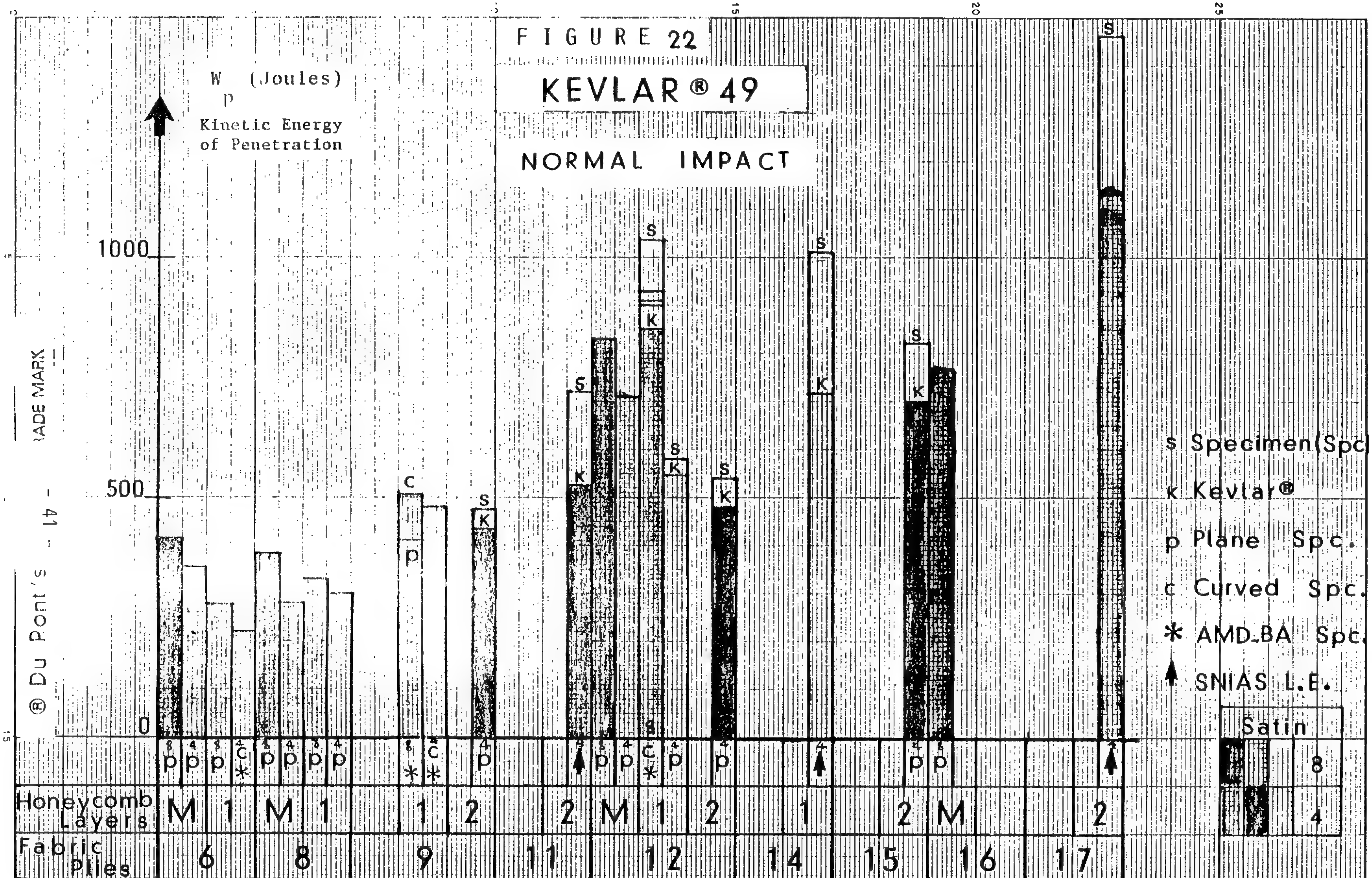


FIGURE 22

KEVLAR® 49

NORMAL IMPACT



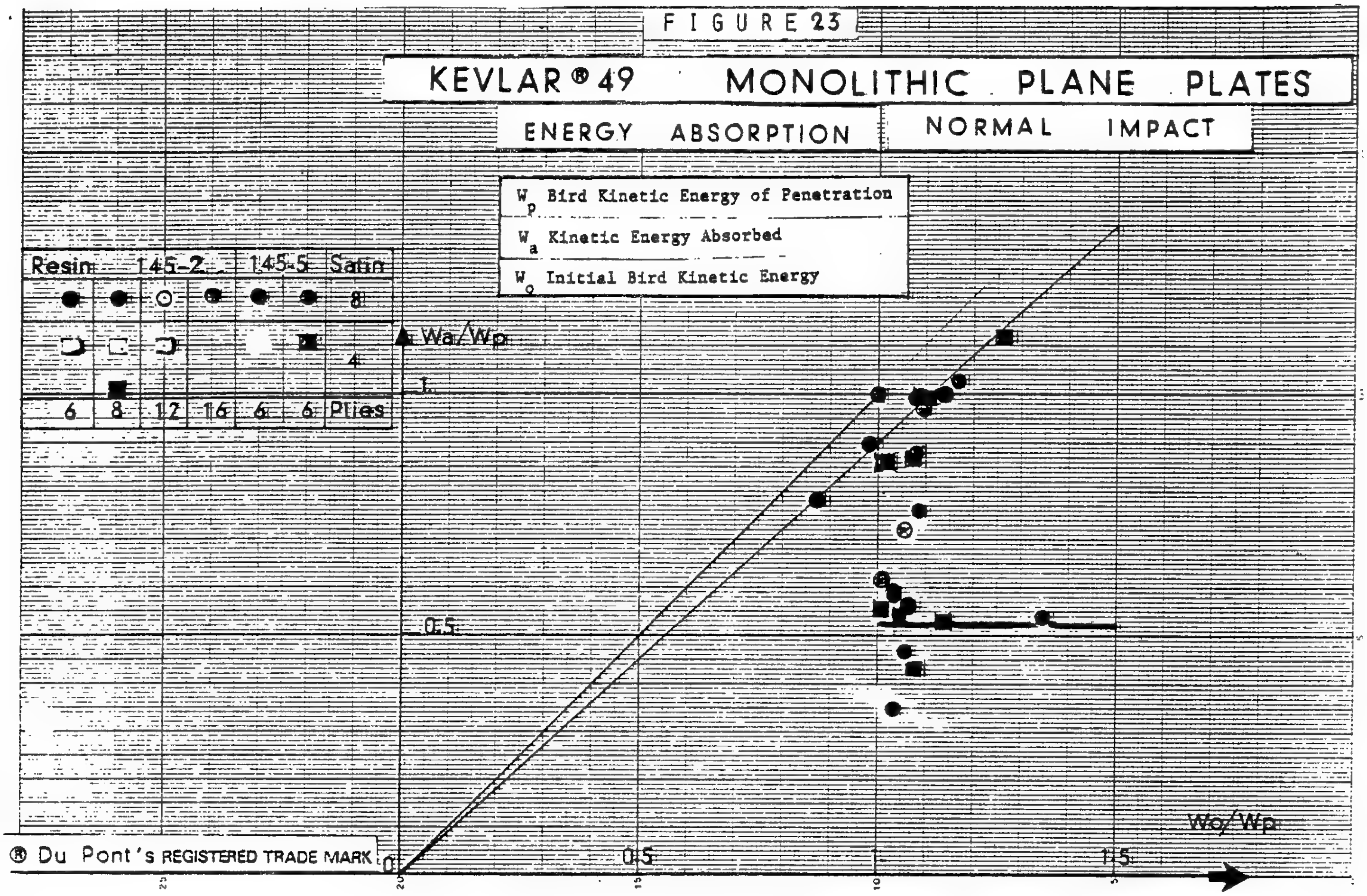


FIGURE 23
KEVLAR ® 49 MONOLITHIC PLANE PLATES
ENERGY ABSORPTION
NORMAL IMPACT
Wp Bird Kinetic Energy of Penetration
Wa Kinetic Energy Absorbed
Wo Initial Bird Kinetic Energy
Resin 145-2 145-5 Satin
8
4
6 8 12 16 6 6 Plies
Wa/Wp
1
0.5
Wo/Wp
0 0.5 1 1.5
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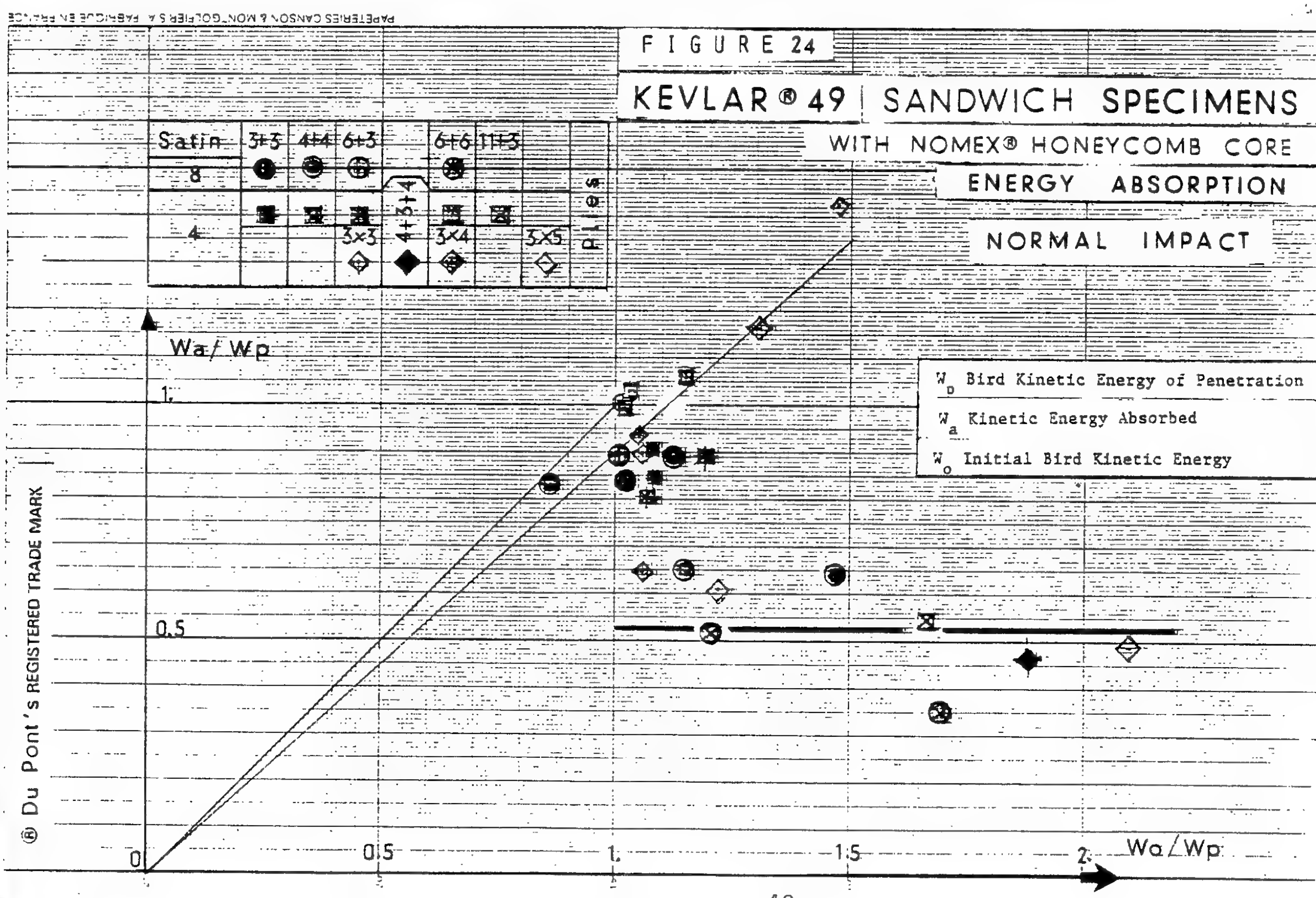
FIGURE 24
KEVLAR ® 49 SANDWICH SPECIMENS
WITH NOMEX® HONEYCOMB CORE
ENERGY ABSORPTION
NORMAL IMPACT
Satin 3+3 4+4 6+3 6+6 11+3
8
4
3×3 4+3+4 3×4 3×5
Plies
Wa/Wp
1
0.5
Wp Bird Kinetic Energy of Penetration
Wa Kinetic Energy Absorbed
Wo Initial Bird Kinetic Energy
0 0.5 1 1.5 2 Wo/Wp
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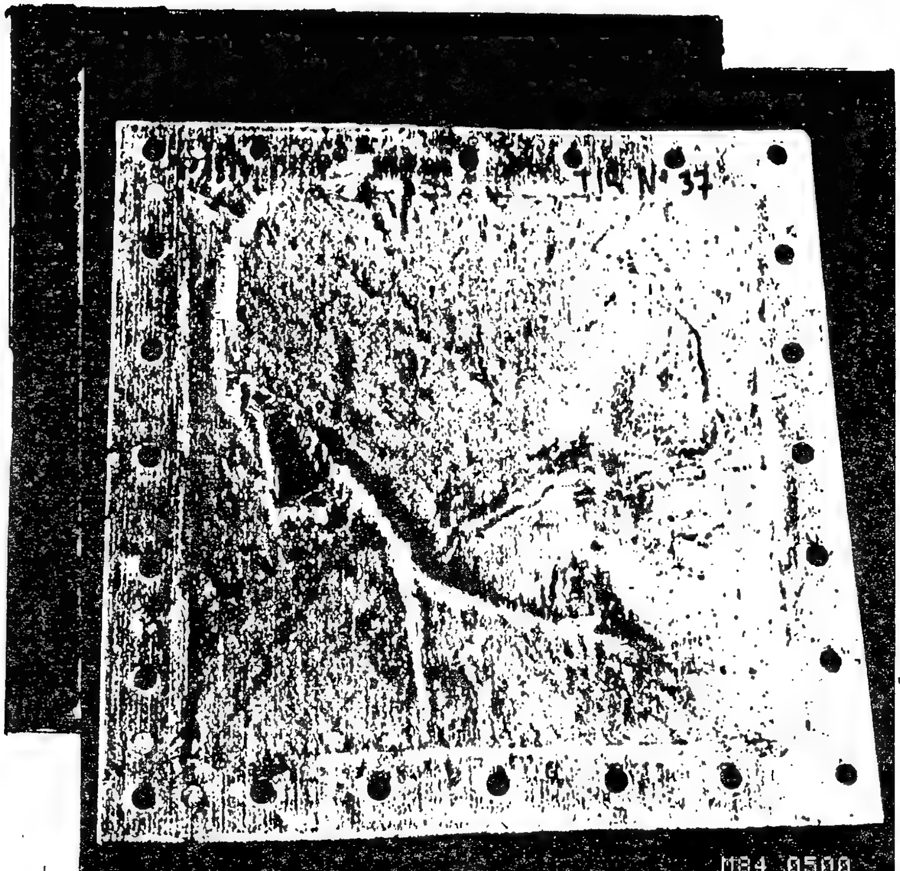
FIGURE 25

MONOLITHIC PLANE PLATES

NORMAL IMPACT

FAILURE PATTERN



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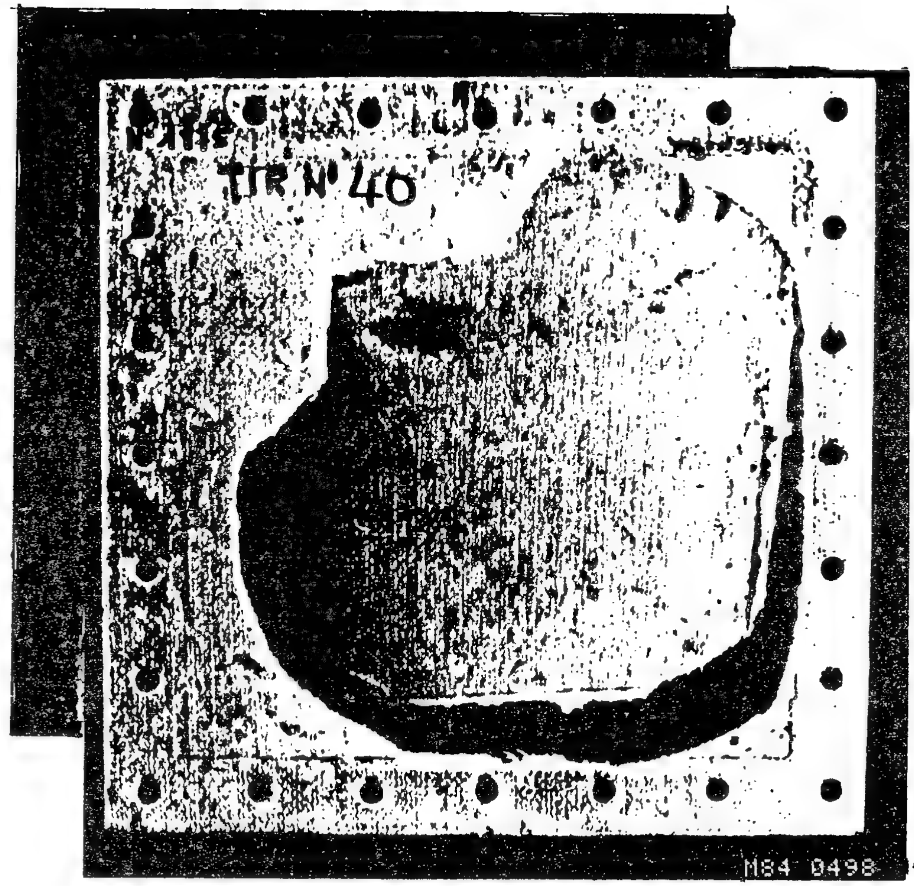

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FIGURE 26

PLANE PLATES SANDWICH

WITH ONE LAYER OF NOMEX® HONEYCOMB CORE

NORMAL IMPACT

FAILURE PATTERN

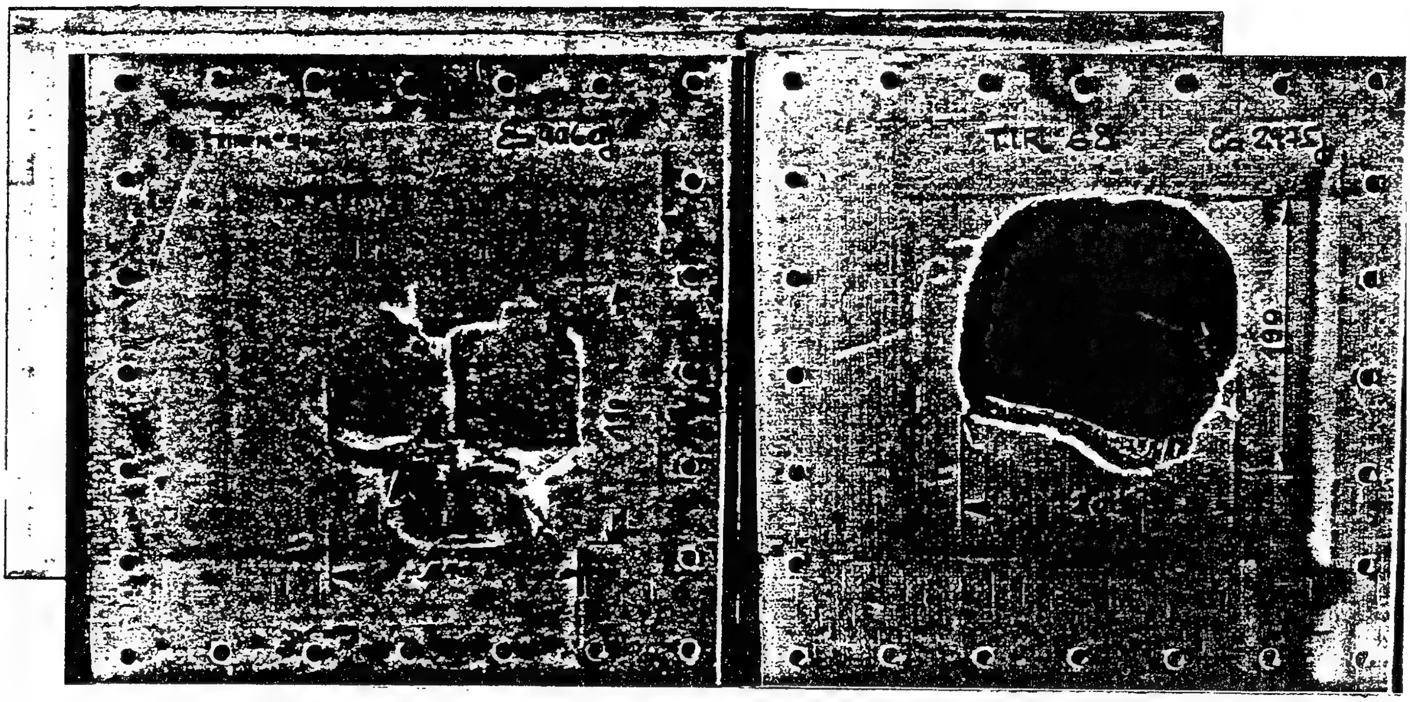

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FIGURE 27

PLANE PLATES SANDWICH

WITH TWO LAYERS OF HONEYCOMB

NORMAL IMPACT

FAILURE PATTERN

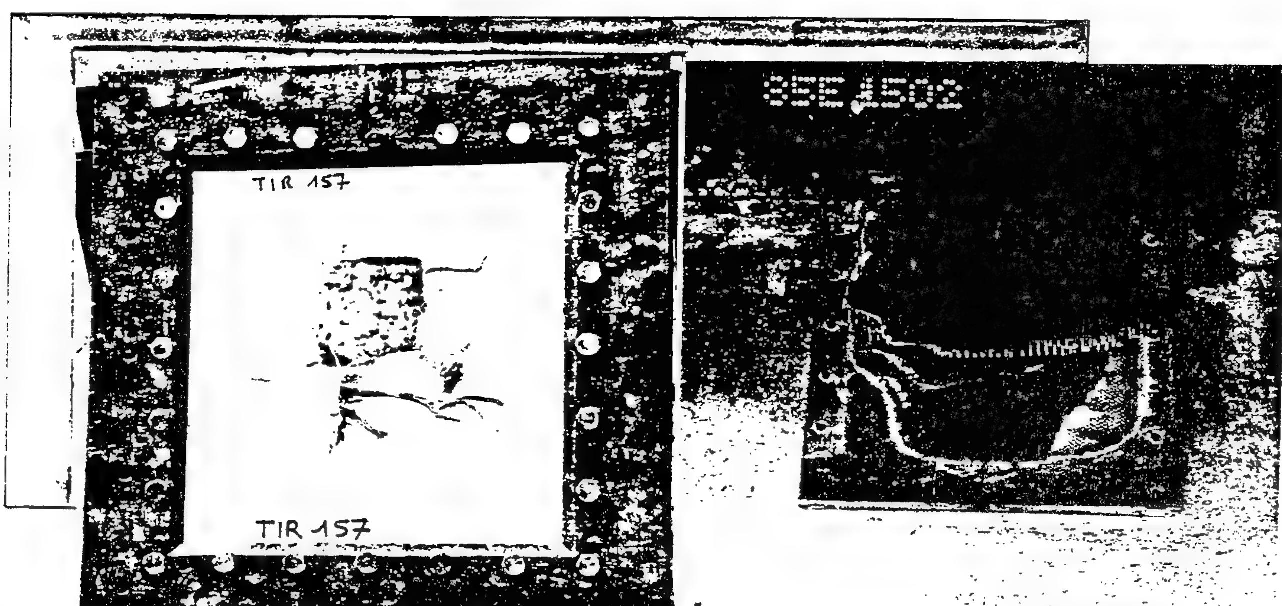

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FIGURE 28

SANDWICH CURVED SPECIMENS

NORMAL IMPACT

FAILURE PATTERN

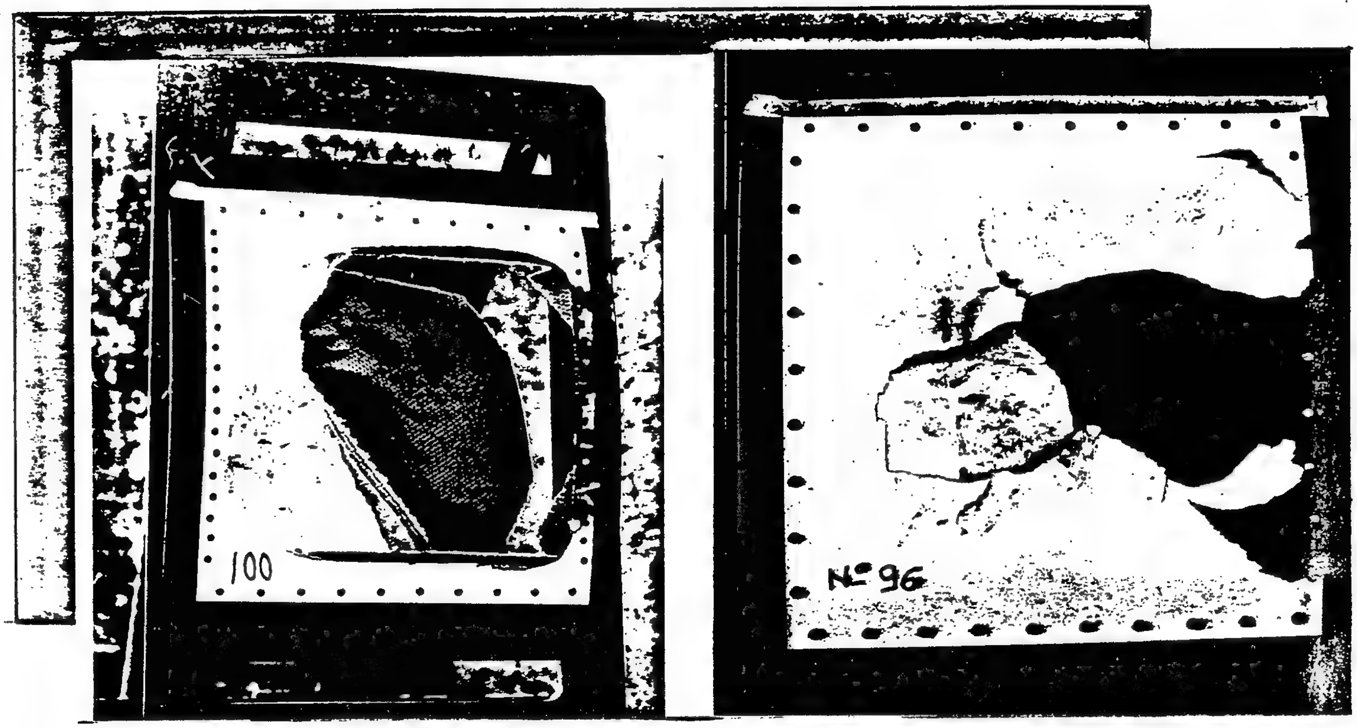

FIGURE 29

SANDWICH CURVED SPECIMENS

FAILURE PATTERN

FIGURE 30

KEVLAR ® 49 MONOLITHIC PLANE PLATES

COMPARISON WITH 2024 T351

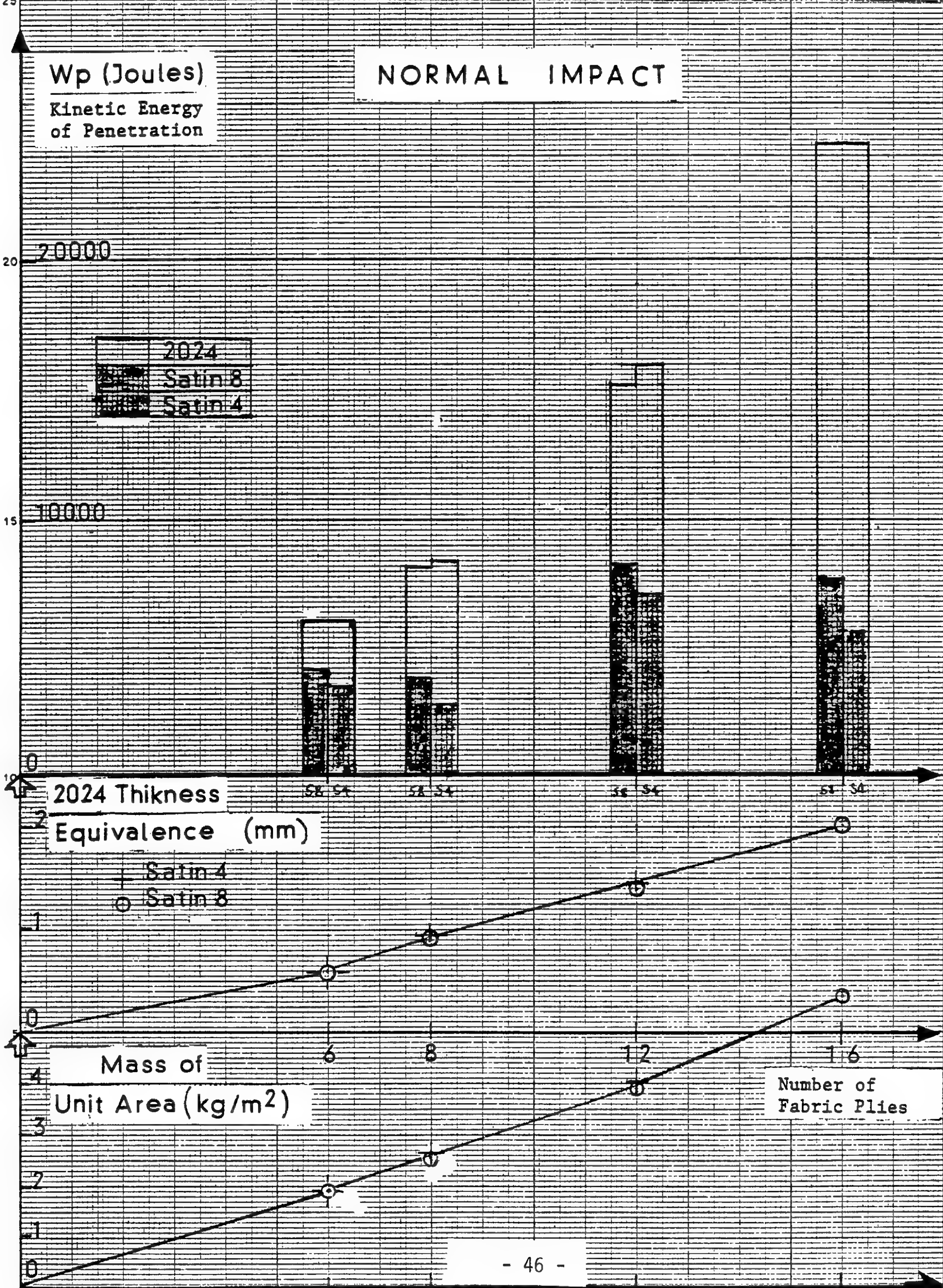

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FIGURE 31

KEVLAR® 49 PLANE PLATES

Range of Kinetic Energy / Velocity Tested

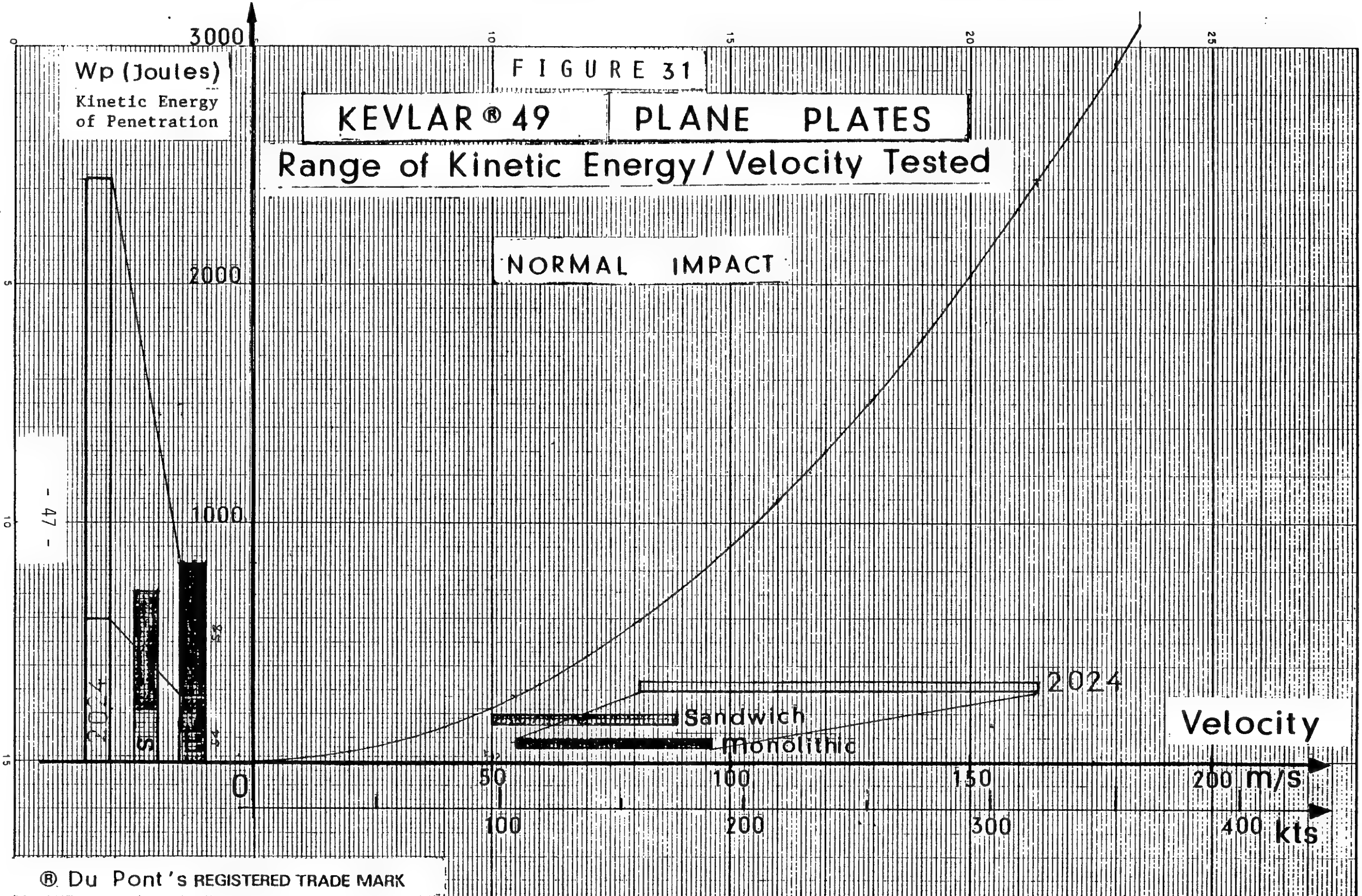

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FIGURE 32

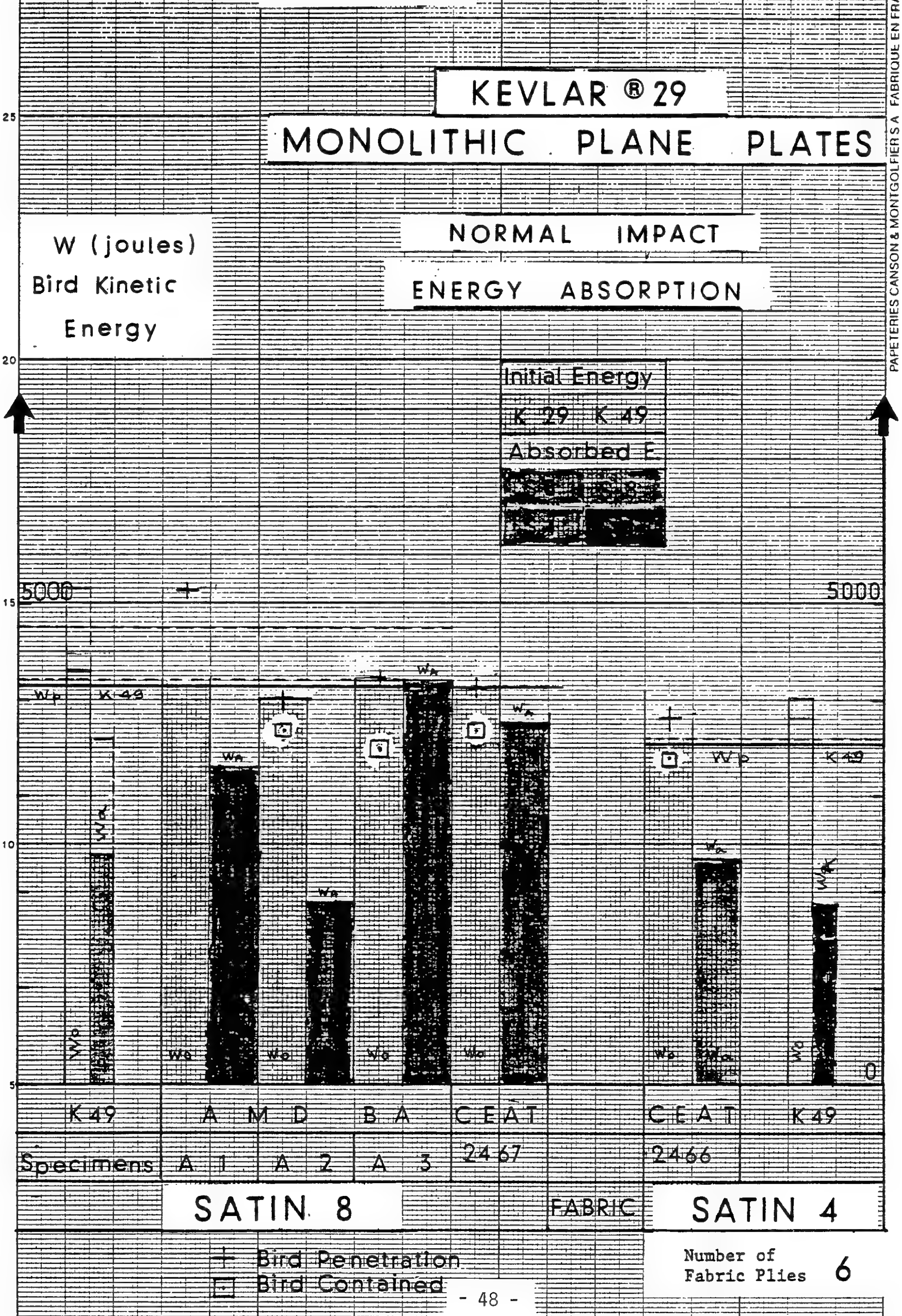

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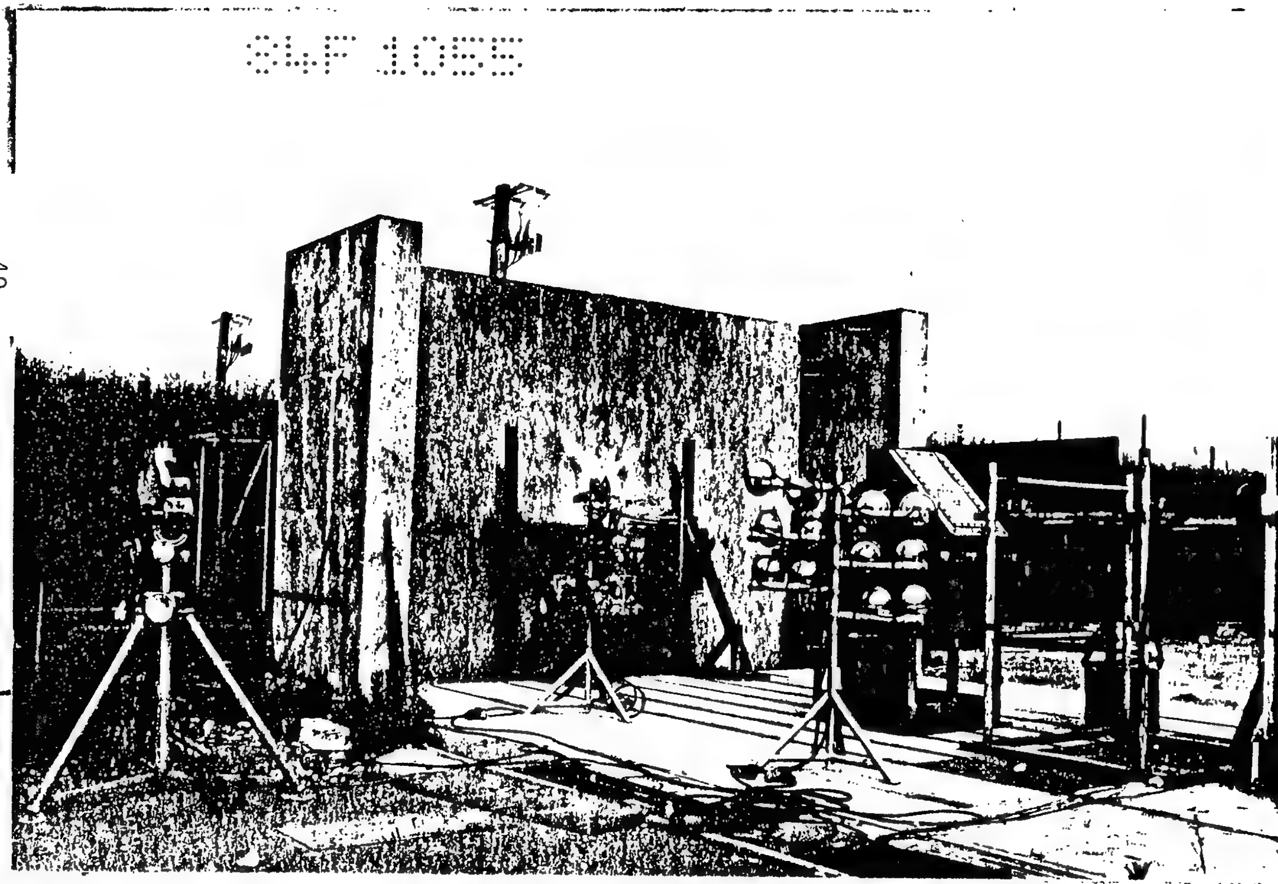
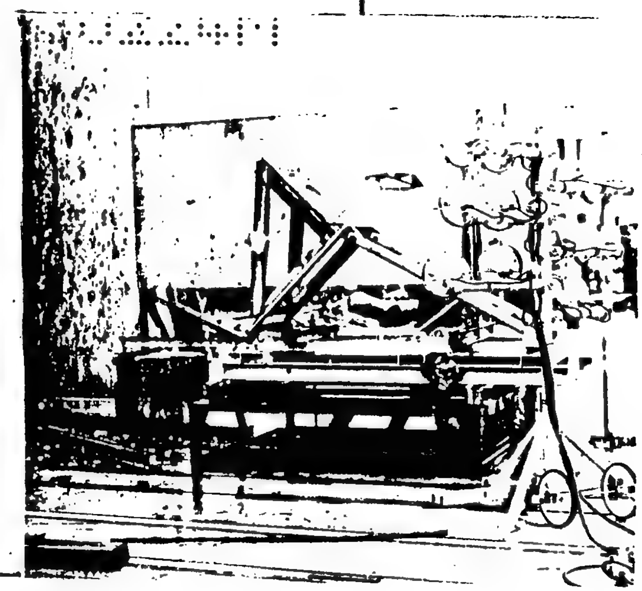
FIGURE 33

OBLIQUE IMPACT PRELIMINARY TESTS



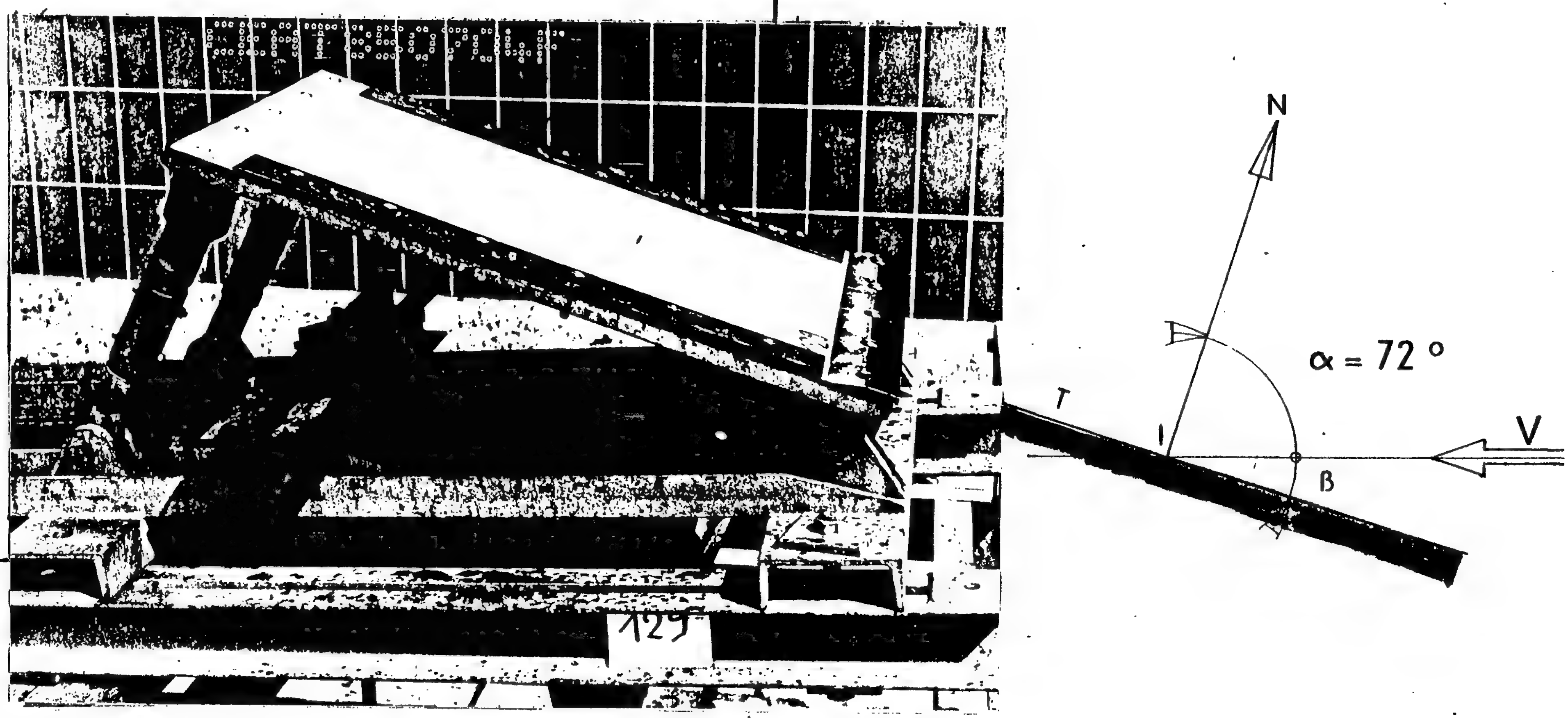


INITIAL TARGET SUPPORT

FIGURE 34

AMD-BA MONOLITHIC PLANE PLATES

PERIPHERAL ATTACHMENT



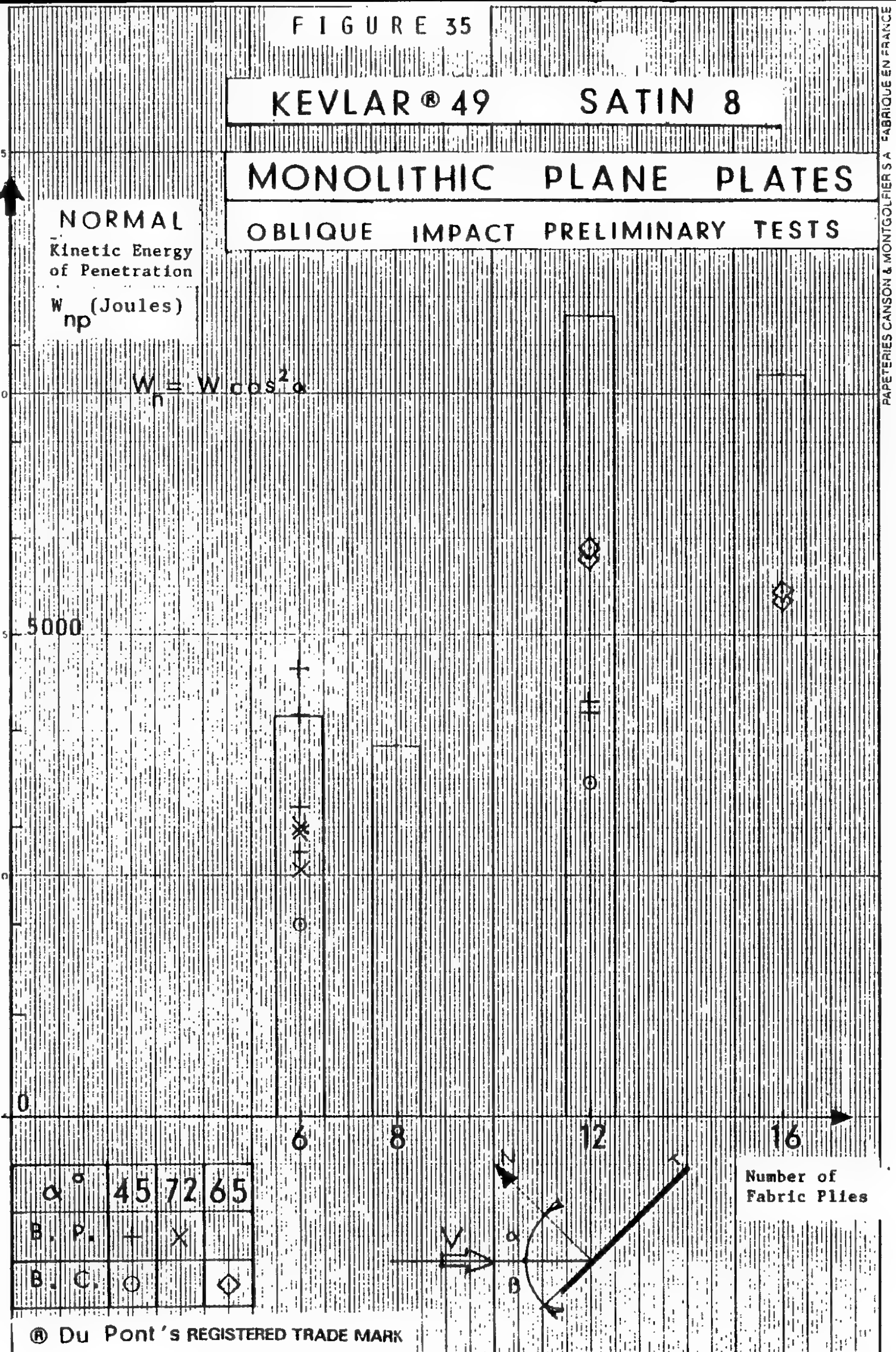


FIGURE 35
KEVLAR® 49 SATIN 8
MONOLITHIC PLANE PLATES
OBLIQUE IMPACT PRELIMINARY TESTS
NORMAL
Kinetic Energy
of Penetration
W_{np} (Joules)
$W_n = W \cos^2\alpha$
5000
0
6
8
12
16
Number of
Fabric Plies
α° 45 72 65
B. P. + ×
B. C. ○ ◇
® Du Pont's REGISTERED TRADE MARK

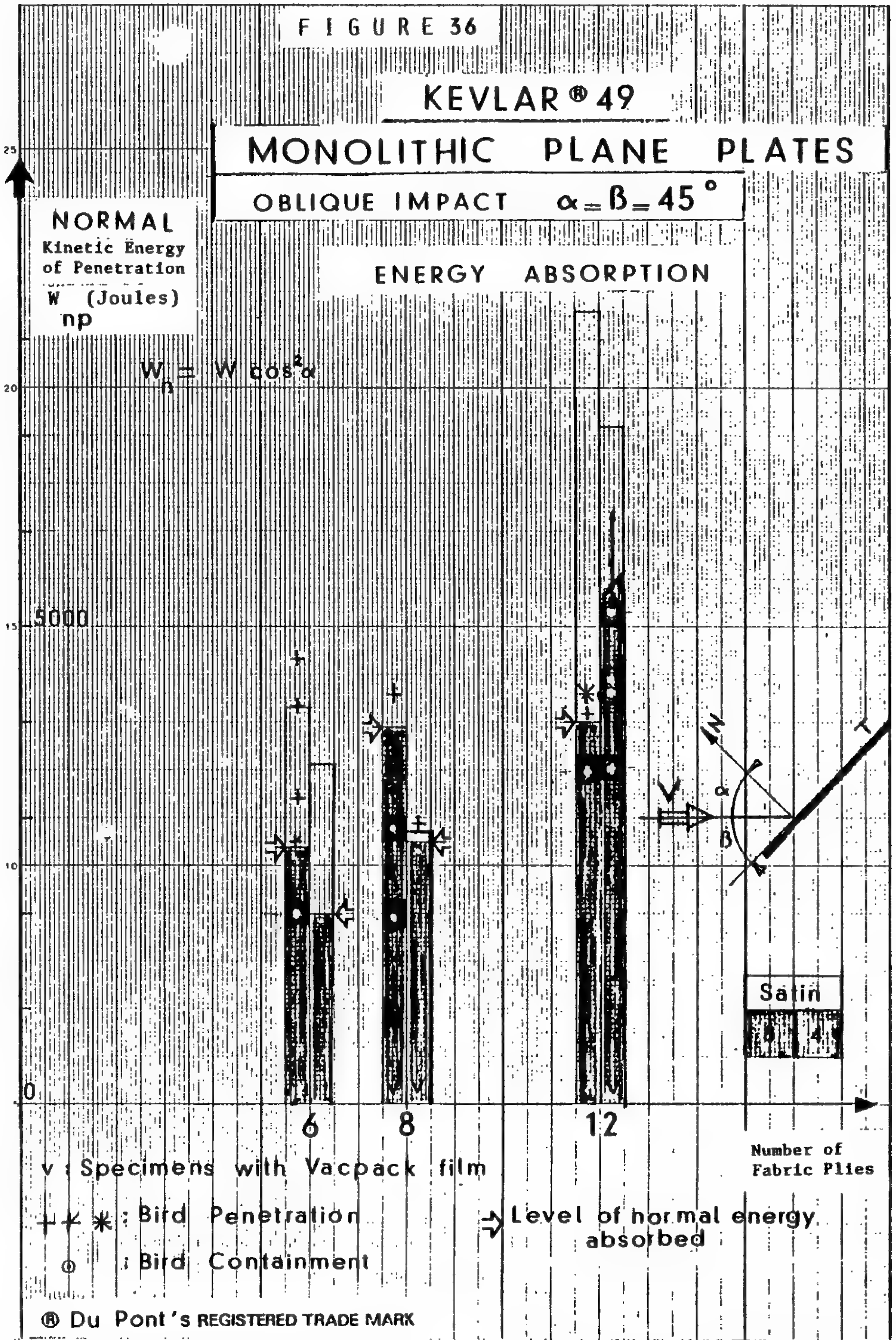


FIGURE 36
KEVLAR® 49
MONOLITHIC PLANE PLATES
OBLIQUE IMPACT α = β = 45°
ENERGY ABSORPTION
NORMAL
Kinetic Energy
of Penetration
W_{np} (Joules)
$W_n = W \cos^2\alpha$
5000
0
6
8
12
Number of
Fabric Plies
Satin
v : Specimens with Vacpack film
+ ✱ : Bird Penetration
○ : Bird Containment
⇨ Level of normal energy absorbed
® Du Pont's REGISTERED TRADE MARK

FIGURE 37

AMD-BA SANDWICH CURVED SPECIMEN

Support For Oblique Impact

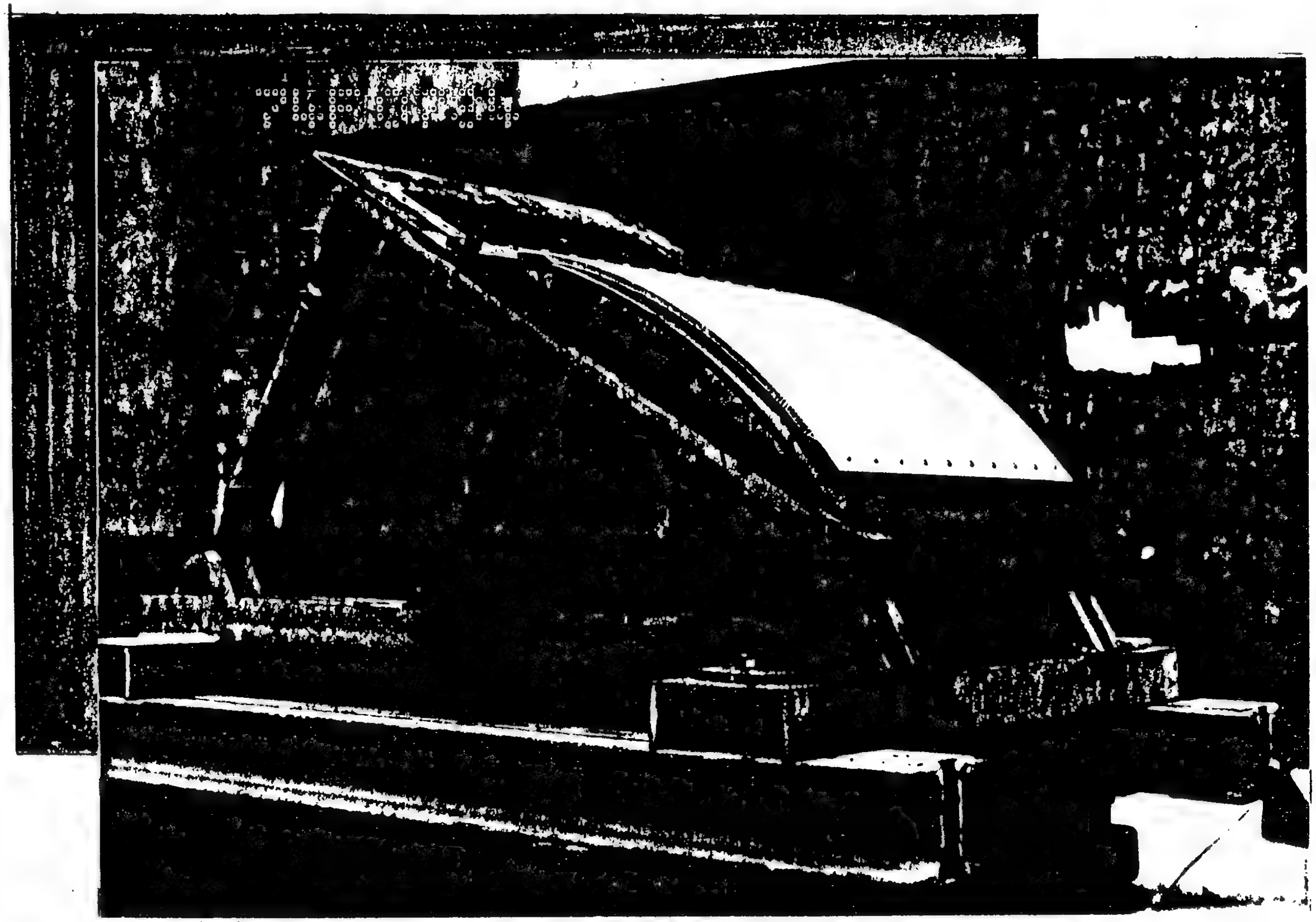


FIGURE 38

AMD-BA SANDWICH CURVED SPECIMEN

Oblique Impact $\alpha=60°$

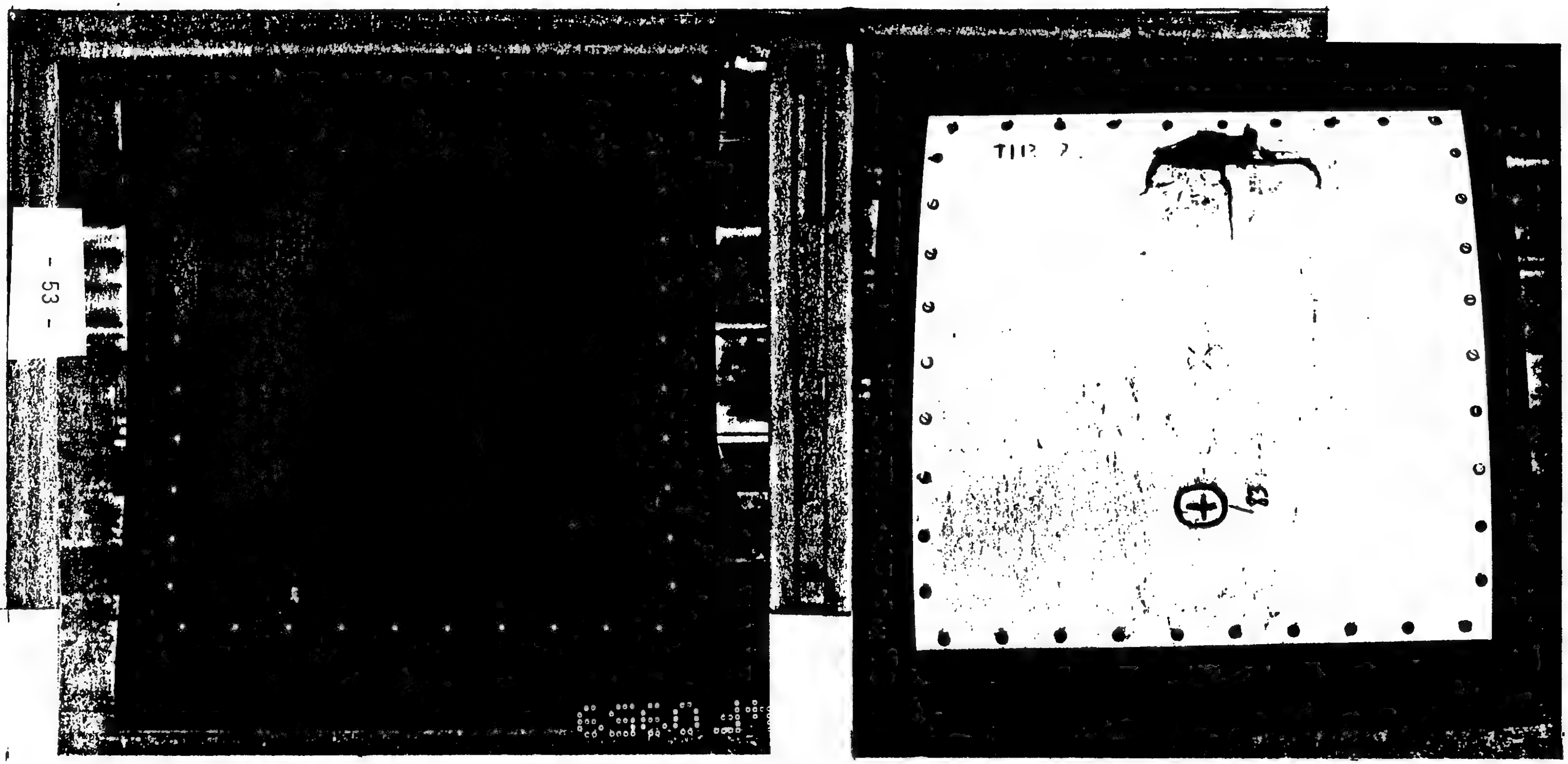


FIGURE 39

AMD-BA PLANE PLATES SANDWICH

WITH 2024 SKIN

Top and Bottom Attachment

INSTALLATION OF TEST SPECIMEN

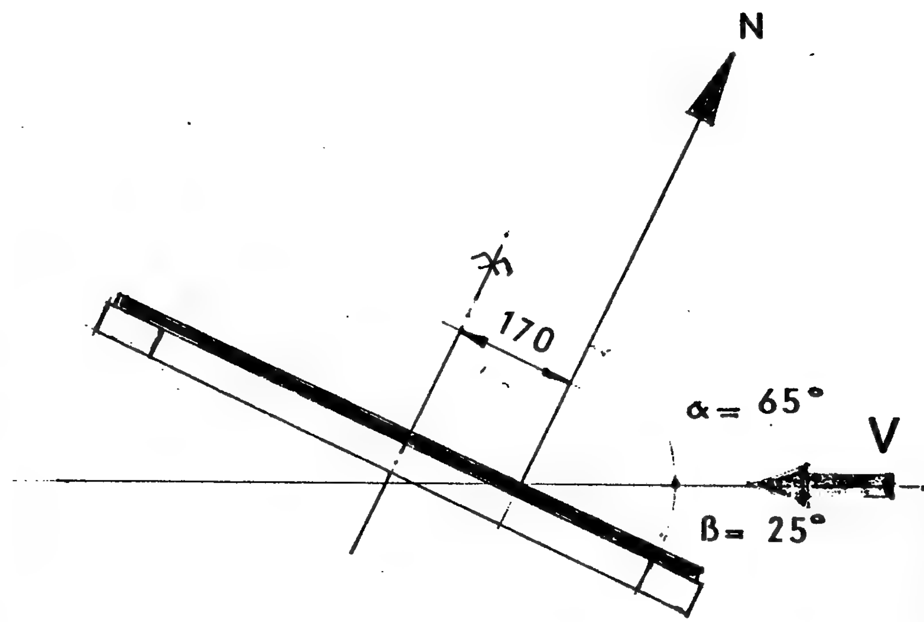
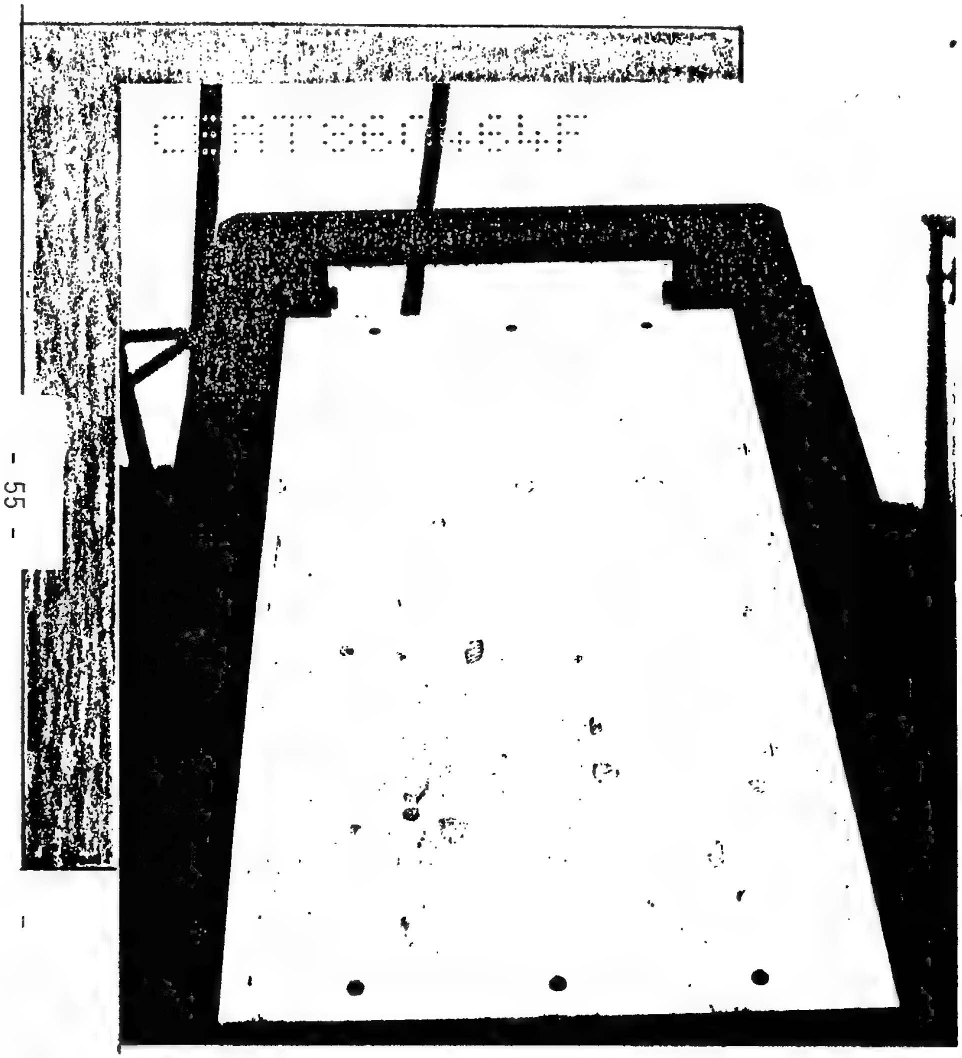


FIGURE 40

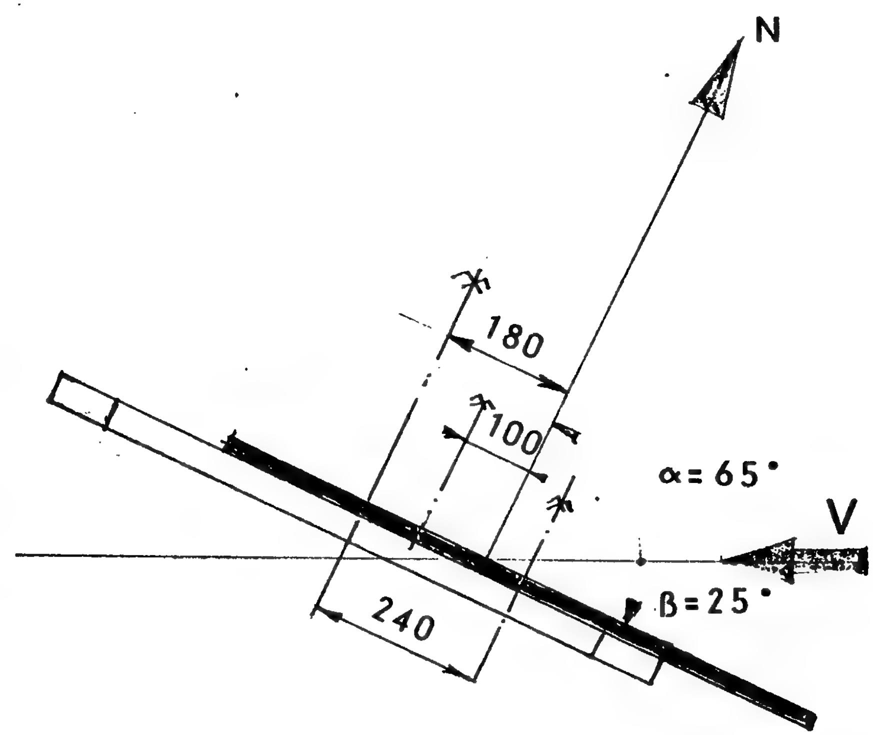
AMD-BA PLANE PLATES SANDWICH

WITH 2024 SKIN



Lateral Attachment

INSTALLATION OF TEST SPECIMEN



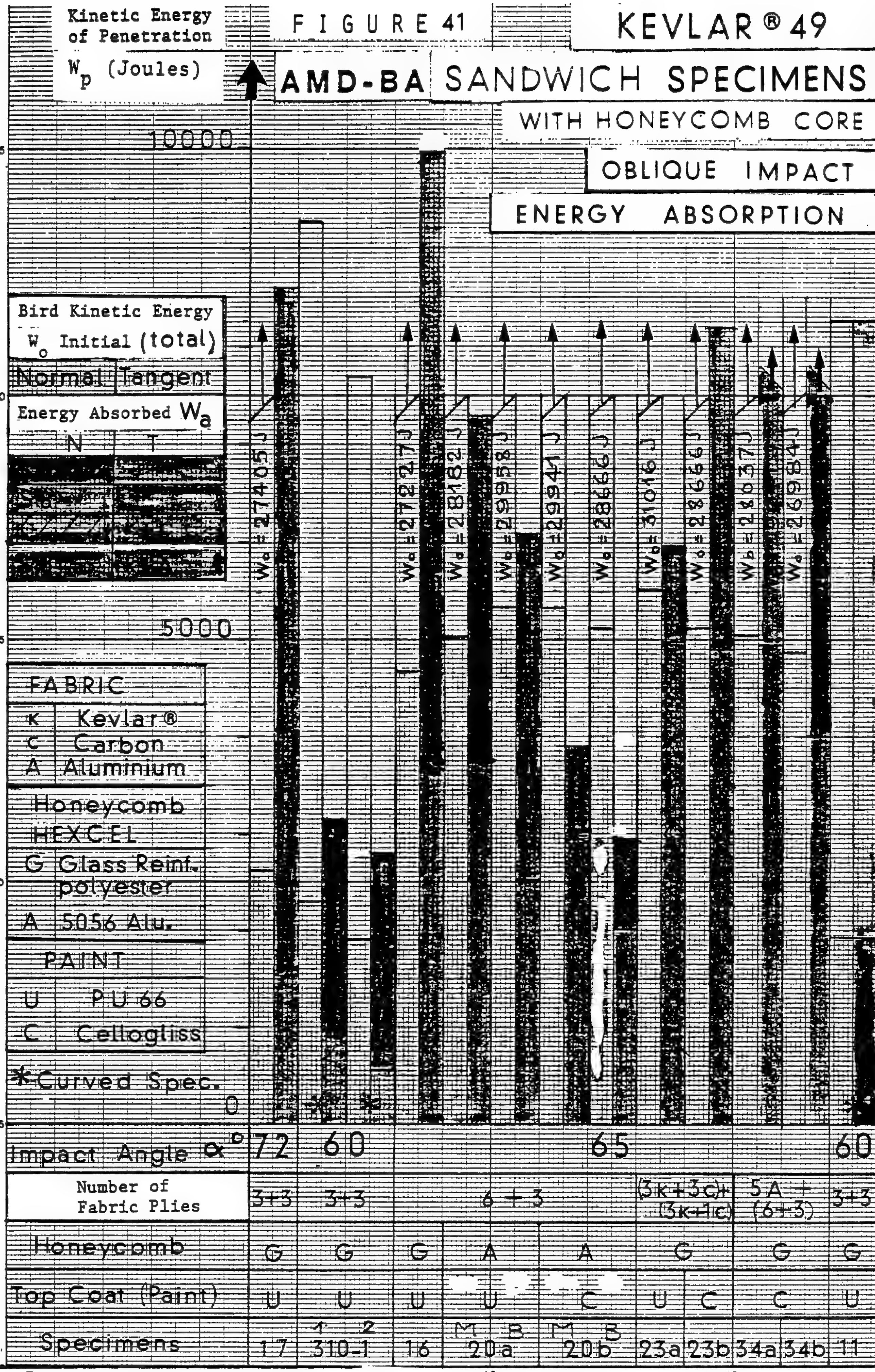


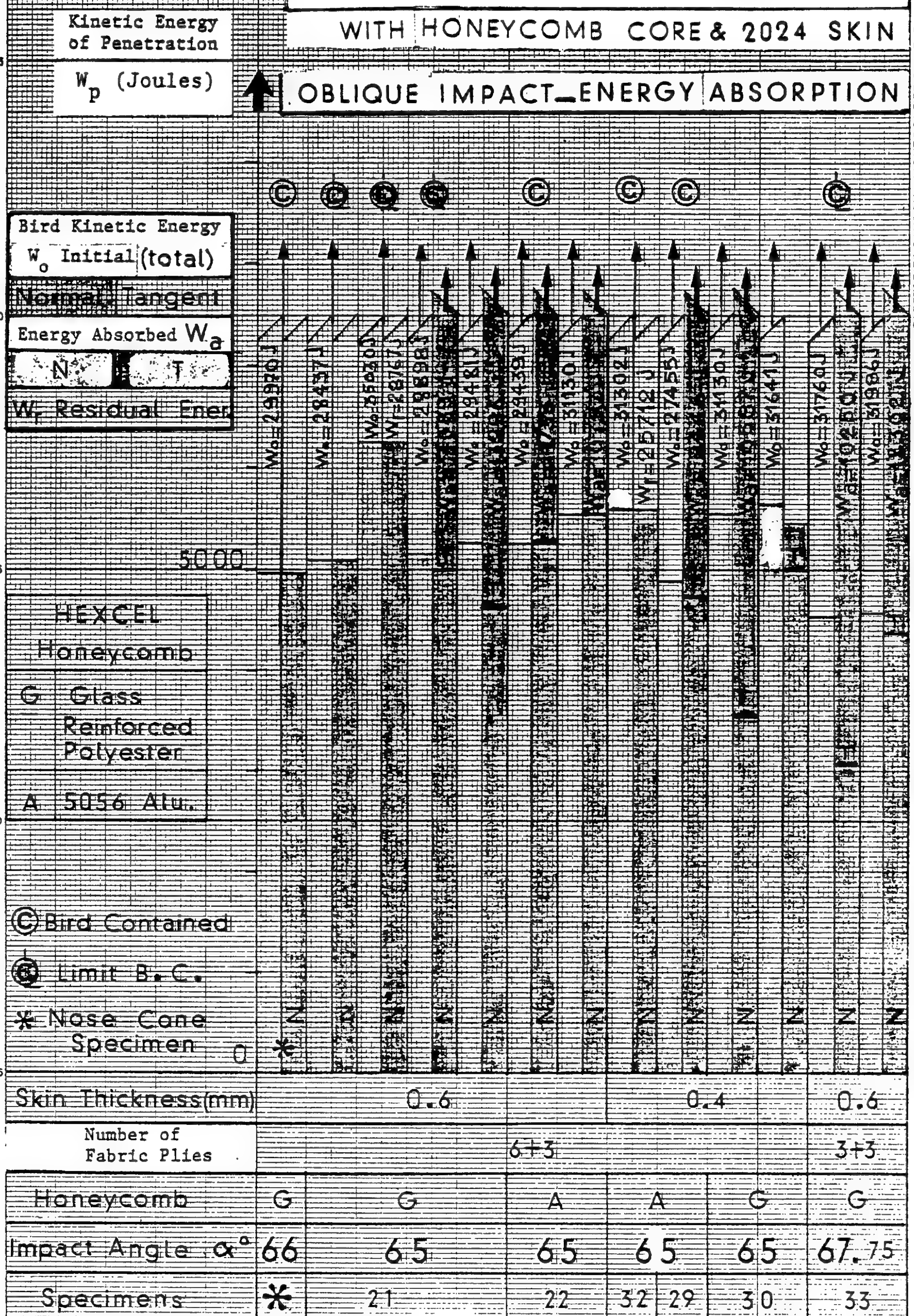
FIGURE 41
KEVLAR® 49
AMD-BA SANDWICH SPECIMENS
WITH HONEYCOMB CORE
OBLIQUE IMPACT
ENERGY ABSORPTION
Kinetic Energy of Penetration
Wp (Joules)
10000
5000
0
Bird Kinetic Energy
Wo Initial (total)
Normal
Tangent
Energy Absorbed Wa
N
T
FABRIC
K Kevlar®
C Carbon
A Aluminium
Honeycomb
HEXCEL
G Glass Reinf. polyester
A 5056 Alu.
PAINT
U PU 66
C Cellogliss
*Curved Spec.
Wo = 27405 J
Wo = 27227 J
Wo = 28182 J
Wo = 29958 J
Wo = 29941 J
Wo = 28666 J
Wo = 31016 J
Wo = 28666 J
Wo = 28637 J
Wo = 26984 J
Impact Angle α°
72
60
65
60
Number of Fabric Plies
3+3
3+3
6 + 3
(3K+3C)+(3K+1C)
5A + (6+3)
3+3
Honeycomb
G G G A A G G G
Top Coat (Paint)
U U U U C U C C U
Specimens
17
310-1 (1, 2)
16
20a (M, B)
20b (M, B)
23a
23b
34a
34b
11

FIGURE 42 KEVLAR® 49 SATIN 8

AMD-BA SANDWICH SPECIMENS

WITH HONEYCOMB CORE & 2024 SKIN

OBLIQUE IMPACT—ENERGY ABSORPTION



® Du Pont's REGISTERED TRADE MARK

FIGURE 43

AMD-BA NOSE CONE TEST SPECIMEN

Installation of Test Specimen

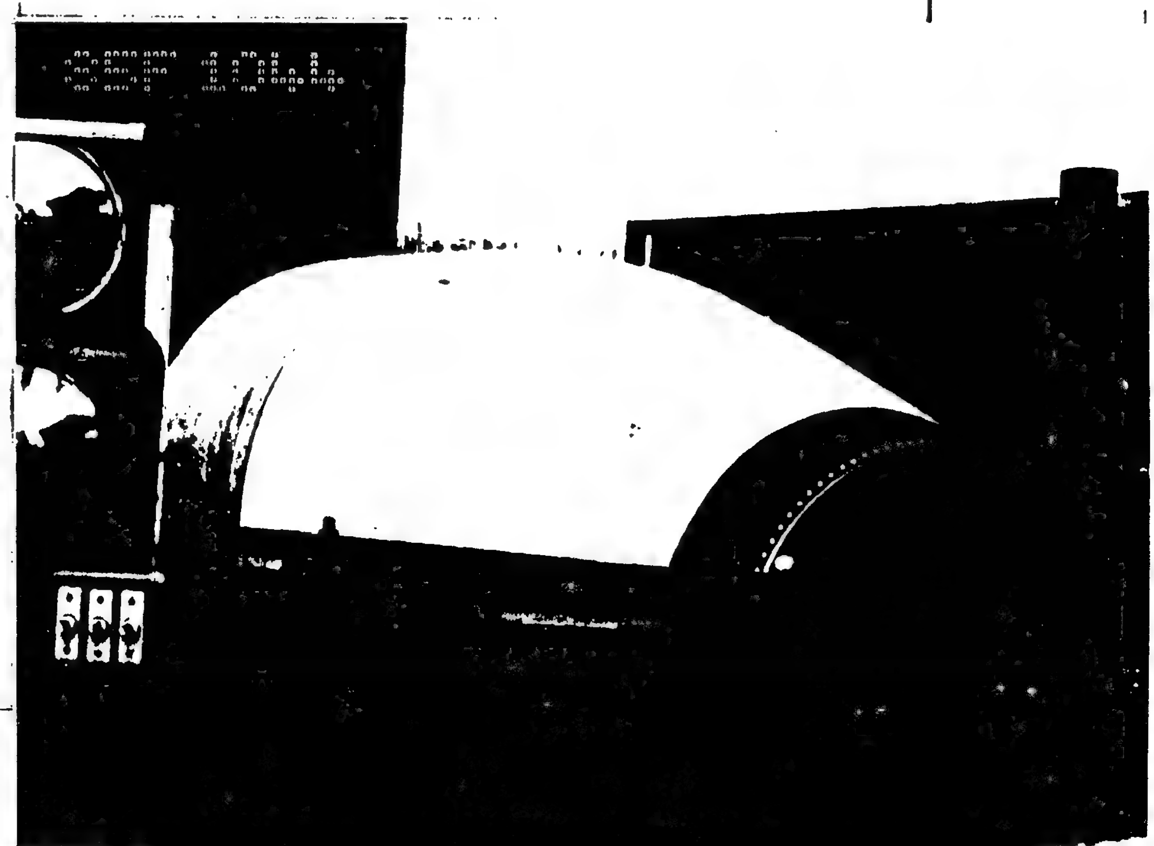
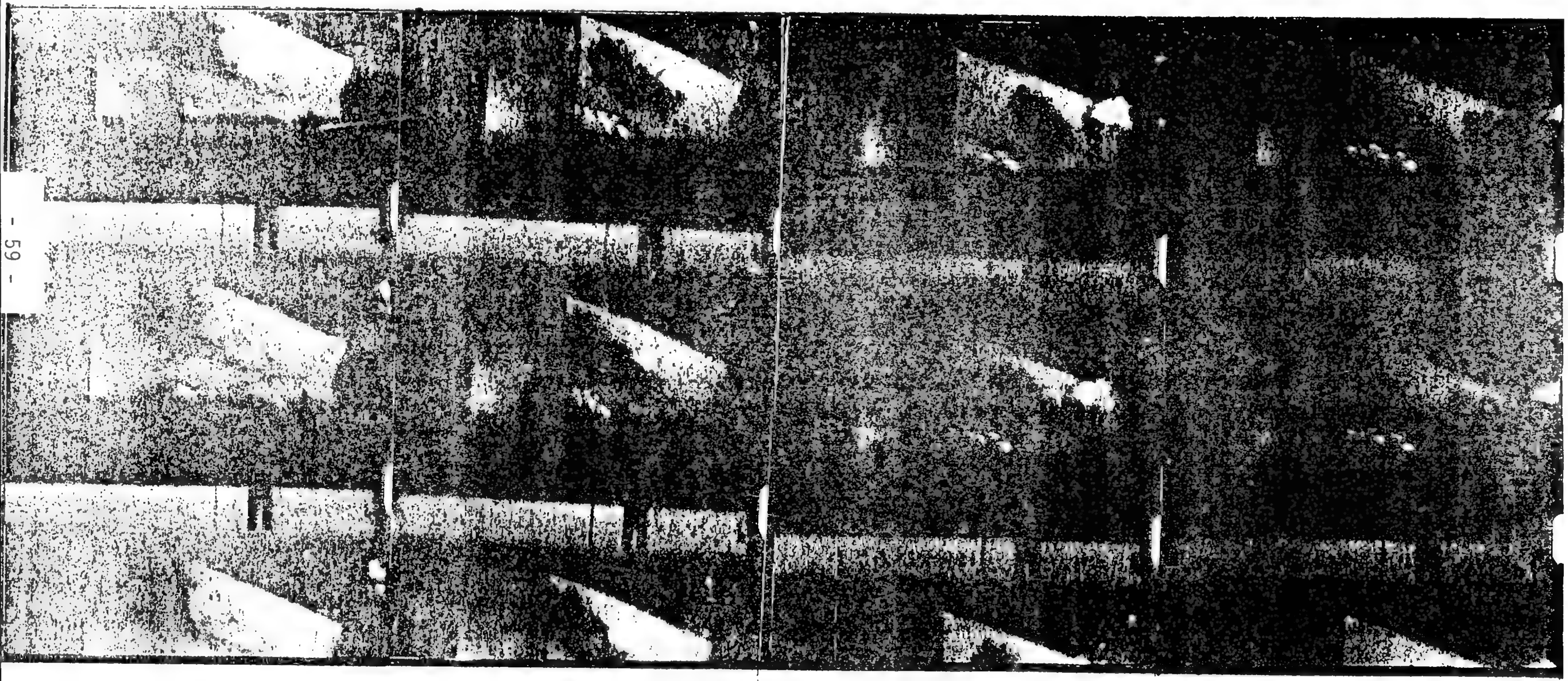


FIGURE 44

AMD-BA NOSE CONE TEST SPECIMEN

EXCERPTS FROM TEST PICTURE



BSCE 18/WP 3
Copenhagen May 1986

ADF616043

PROPERTIES OF THE AUDITORY SYSTEM IN BIRDS AND THE EFFECTIVENESS OF ACOUSTIC SCARING SIGNALS

Karl J. Beuter and Rainer Weiss,
Battelle Frankfurt

1 SUMMARY

The effectiveness of sound signals for scaring gulls away from feeding areas have been investigated during the last years. Physiological and behavioural data were used to identify the most promising approach. Ultrasound and infrasound were tested as well as audible sound at different frequencies and with a large variety of modulations.

The investigations have shown that ultrasound and infrasound do not produce the desired scaring effect, where as a group of frequency-modulated audible signals have proved effective for bird control. The scaring signal can be generated by an electroacoustic device. Based on the encouraging results of investigations conducted on behalf of two major German cities, functional models of the bird control device have been developpped for an industrial client.

Fundamental properties of the bird's ear and some results of a field test to scare away gulls from waste deposits are described in the following paper.

2 IMPORTANCE OF ACOUSTIC SIGNALS

Birds can be scared away by humans, animals, scarecrows, light, microwaves, aircrafts, chemicals and sound. But laws and environmental protection make it necessary to select carefully among the different methods /1/. Automatic or controlled operation is also often desired. Important selection criteria for scaring devices ar their

- Efficiency
- Ease of operation and
- Compatibility with the environment.

These criteria may contradict each other in some cases. For instance, a very effective chemical can pollute the water, or another technique may need a full time operator. As a consequence, it is generally not possible to find a device which fulfills all selection criteria. So one should try to find specific solutions for given applications.

Acoustic methods offer some interesting advantages /2/:

- Acoustic signals have important functions in the behaviour of birds.

- Sound is a relatively far reaching signal and is well suited to cover large areas.

- Acoustic signals can be easily combined with other effects to produce conditioning stimuli.

All kinds of sound-wave emitting equipment will be considered here as potential bird scaring device, no matter if the sound is in the normal hearing frequency range of humans or at ultrasonic or infrasonic frequencies. Mechanical sound sources, pyroacoustics, guns, electroacoustic generators and ultrasound sirens are typical acoustic bird scaring devices.

This article deals mainly with gulls, a bird species which is important in bird strikes due to its relatively high bodyweight and its appearance in large flocks. The method used in gulls can be applied to find appropiate sound signals for other species like crows, starlings, peewits, pigeons and possibly birds of prey.

3 EFFECTS OF SOUND IN HUMANS AND ANIMALS.

3.1 Physical characteristics of sound.

The subjective loudness is closely related to the sound pressure level, measured in dB re 0,00002 Pa. In short pulses, the duration of the signal contributes to the perceived loudness, too. The pitch of a pure tone is physically-described by its frequency in Hz and the structure of a complex sound is in part described by its frequency spectrum.

The sensitivity of the hearing organ is not constant over the hearing frequency range but depends strongly on frequency. In order to estimate the subjective effect of sound signals, one has to consider the spectral sensitivity of the ear. A good indicator for the spectral sensitivity is the auditory threshold, which has been measured for many species.

Auditory threshold curves for birds are given in fig.1 and for humans in fig.2. One can see, that in the neighborhood of regions of best hearing there exist frequency ranges with clearly reduced sensitivity. These regions are obviously species specific and differ strongly between mammals and birds.

Therefore, the resulting perceived loudness depends on the incoming sound pressure level weighted by the frequency-dependant auditory sensitivity function. Since the sensitivity function is different in humans and in birds, the resulting subjective loudness will be different as well.

The sound pressure level and the frequency spectrum are only the most simple physical parameters to characterize sound signals. But there are many more significant features, which contribute to the information contained in the signal. The essential components in the acoustical communication signals of birds are generally not yet known and must be identified very thoroughly in behavioural experiments under natural conditions.

3.2 Communication signals

Communication signals often exhibit complex frequency-time-structures and they are species specific. Human language covers the frequency range between 250 Hz and 10 kHz, but communication is still possible in a limited frequency interval between 500 Hz and 2500 Hz. The peak sound pressure levels at 1 m distance and normal speech are about 60 dB and about 75 dB during shouting. Singing birds use sound pressure levels at about 70 dB, but much higher levels e.g. 120 dB in echolocating bats have been observed in bioacoustics. The highest frequencies with about 130 kHz have been measured in bats and in dolphins. Rodents, for example mice, use ultrasound up to 90 kHz /3/. In bird songs only frequencies up to 10 kHz have been found. At the lower frequency end of bird songs, several hundred Hz were observed.

3.3 Biological effects of sound

The ear is the adequate and most sensitive organ for sound reception. Depending on the structure and behavioural meaning of the sound stimuli one can achieve dramatic effects at very low sound intensities.

High sound pressure levels result in temporary loss of hearing sensitivity (temporary threshold shift). Permanent or frequent exposition to these levels may cause permanent damage. This occurs typically at levels above 80 dB. At much higher levels of about 130 dB sound causes pain in humans. At this level extraaural effects like sickness start to occur. Ultrasound and Infrasound at levels above 140 dB have similar effects.

Technically it is very difficult or expensive to produce and radiate sound signals except bangs at levels above 130 dB. Therefore, acoustical devices should use the high sensitivity of birds in response to behaviourally relevant sound structures and should not try to produce uncontrolled effects on birds by high acoustic energies.

3.4 Hearing thresholds in birds and small mammals

In general, the upper edge of the hearing frequency range increases, as the body weight decreases. This has been verified in mammals, but not in birds. The upper frequency edge in the hearing threshold of mice and the corresponding frequency contents in their communication sounds is at about 80 kHz, but one cannot find similarities in the auditory data of birds. As shown in fig.2, the frequencies of best hearing in birds are between 1 kHz and 4 kHz and very high threshold levels in birds start below 11 kHz.

From these data one can conclude that birds are unable to hear frequencies above 11 kHz. Therefore hearing sensitivity at ultrasonic frequency in birds can be excluded. In addition, there are no hints from behavioural experiments or from sound recordings which give any evidence that ultrasound could be meaningful for birds.

4 METHODS FOR MEASURING THE SCARING EFFICIENCY OF SOUND SIGNALS

Audible sound, infrasound and ultrasound were used as stimuli for gulls in neurophysiologigal and behavioural experiments. In the neurophysiologigal study, evoked potentials from the midbrain of gulls were measured. With this very sensitive method hearing thresholds from 1 Hz up to 25 kHz were determined.

Experiments with free living gulls were conducted in a municipal purification plant. The high number of animals and the easy access to the plant allowed us, to place the sound sources very near to the animals and to apply high sound intensities. The sound sources were positioned several days before the experiment took place. So the gulls were used to the equipment. The scaring efficiency of the sound signals was registrated on a scale from one to six.

5 RESULTS

5.1 Neurophysiology

Ultrasonic hearing threshold:

In four animals measurements were taken between 16 kHz and 20 kHz and in one animal up to 25 kHz. Stimuli up to 110 dB at the ear were used. No indication for hearing was found.

Infrasonic hearing threshold:

In guinea fowls a remarkable low infrasound hearing threshold similar to that in pigeons had been measured. With the same method no indication for hearing in the gulls was found.

Hearing threshold between 20 Hz and 16 kHz:

The hearing threshold, determined by electrophysiology, is given in fig. 3. The frequency of best hearing is at about 3 kHz. It is remarkable, that the auditory sensitivity of gulls declines rapidly at lower frequencies. At frequencies below 500 Hz the hearing threshold is above 40 dB.

5.2 Ineffective sound signals

Infrasound of 8 Hz and 10 Hz at levels up to 85 dB could not generate any reaction of the gulls. Also pure tones with frequencies between 20 Hz and 6 kHz at levels below 100 dB could not generate reactions above level one.

Very high ultrasonic levels of 135 dB at frequencies between 18 kHz and 50 kHz did not produce any reaction.

Only pure tones above 100 dB produced strong reactions of the gulls initially (fig. 4). But the birds soon got used to these signals and showed only week reactions even at high sound intensities.

In summary, the following signals were inefficient:

- Infrasound and normal sound at low frequencies
- Pure tones in the normal hearing range
- Ultrasound
- Amplitude-modulated pure tones (AM)
- Noise Signals (Bandpass noise)

5.3 Sound signals for efficient scaring

Strong reactions were observed with frequency-modulated signals. The strength of the reaction was influenced by the parameters:

- Starting frequency f_o
- Frequency span (Bandwidth) B and
- Modulation frequency f_m

A large variety of combinations between these parameters was shown to be effective. Good efficiency with reaction levels of 5 and 6 was found in the following intervals:

$$f_o \approx 200 \text{ Hz}$$
$$0{,}5 \text{ Hz} < f_m < 20 \text{ Hz}$$
$$2 \text{ kHz} < B < 7 \text{ kHz}$$
$$2 \text{ s} < \text{Duration.}$$

With efficient signals, the gulls reacted within two seconds, but at reaction levels below or equal to four they reacted only within ten seconds. Finally, a signal duration of 20 seconds was chosen. With this signal, returning gulls were scared away for a second time, but adaptation to the signals did not occur.

6 TECHNICAL CONCEPT

A group of effective frequency-modulated sound signals with the following properties was selected:

- Frequency span more than 4 kHz
- Modulation frequency between 0,5 Hz and 20 Hz.

These signals proved to be effective also on a waste dump during a period of more than one month. Sound pressure levels down to 60 dB at the birds ears were shown to be effective. An electroacoustic device constructed on this basis consists of a rugged waterproof housing and radiates the sound with a preselected radiation pattern (fig. 5). It has the following properties:

- Battery-powered with low current consumption.

- Automatic and manual trigger.

- Preselectable signal types and duty cycles.

- Maintenance-free operation for one week (running at ten minute-intervals).

- Automatic variation of scaring sounds.

- No mechanical wear off.

- Adaptable to different bird species.

- Fitting to triggering sensors.

Additional experiments on a waste deposit revealed the following observations:

- At high noise exposures (85 dBA) from the environment, the active area was restricted to a radius of 30 meters.

- When the scaring sounds were directed to incoming flocks of birds, they fled away from the sound source: The birds stayed away for 20 seconds up to 15 minutes.

- In quiet surroundings, the typical diameter of effective operation was between 200 m and 400 m.

- When the birds were insonified at their roosting places, they showed very strong flight reactions and stayed away for more than one hour (fig. 6).

- Negative effects on working personnel and on animals in the surrounding areas were not observed. The signal types (250 Hz - 5000 Hz, 90 dBA during 20 s at 10 m distance) are tolerable in working areas.

7 DISCUSSION

In a systematic study it was shown that inaudible sound for humans is also inaudible for birds. The hypothesis of hearing at infrasonic or ultrasonic frequencies in birds must be negated.

The hearing threshold curve of gulls has proved to give a good estimate for the scaring efficiency of wideband sound signals. In additional behavioural experiments, a group of frequency-modulated sound signals with strong scaring effects was identified. They were effective for roosting birds down to sound pressure levels of 60 dB. Not only gulls, but also swarms of starlings were scared away by the signals.

An electroacoustic device was developed on the basis of these results. It is suited for the operation on airfields against incoming and roosting birds. It can be triggered automatically, by radio signals or by bird sensors. Without operator interaction, the device is operable for least one weak, then the batteries should be recharged.

Circular and asymmetric sound beams can be radiated depending on the loudspeaker arrangement. A test on an airfield has been started, but additional experiments on traffic airports are required.

8 LITERATURE

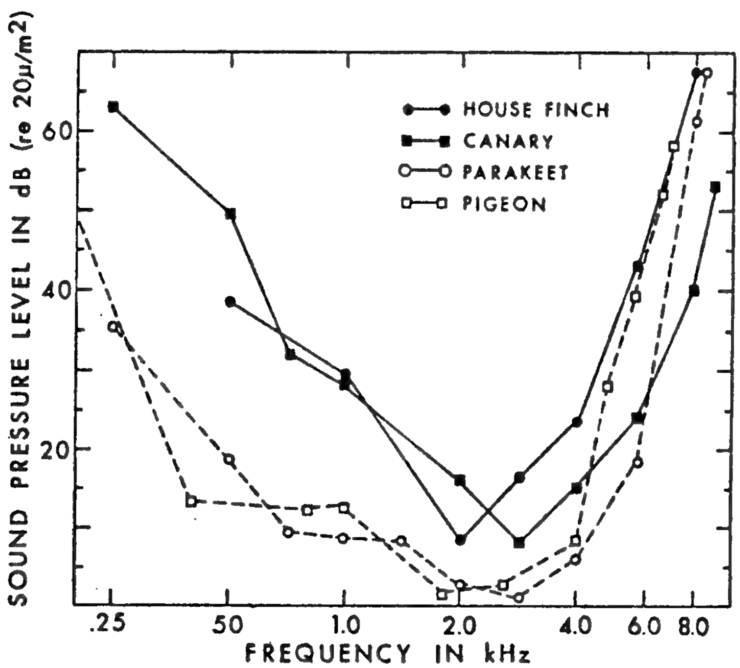
/1/ Hild, J.: Vögel auf Flugplätzen (Biologische Untersuchung, Bekämpfungs- und Vergrämungsmaßnahmen) Merkheft 1, Amt für Wehrgeophysik, 1970

/2/ Keil, W.: Erfahrungen zur phonoakustischen Vertreibung von Staren (Sturnus vulgaris) aus ihren Schlafplätzen. Luscinia 38: 78-85, 1965

/3/ Markl, H. and Ehret, G.: Die Hörschwelle der Maus (Mus musculus). Eine kritische Wertung der Methoden zur Bestimmung der Hörschwelle eines Säugetiers. Z. Tierpsychol. 33: 274-286, 1973

/4/ Dooling, R.J., S.R. Zoloth and J.R. Baylis: Auditory sensitivity, equal loudness, temporal resolving power and vocalizations in the house finch (Carpodacus mexicanus). J. Comp. Physiol. Psychol. 92: 767-876, 1978

FIGURE 1: Auditory threshold curves in birds and small mammals /4/



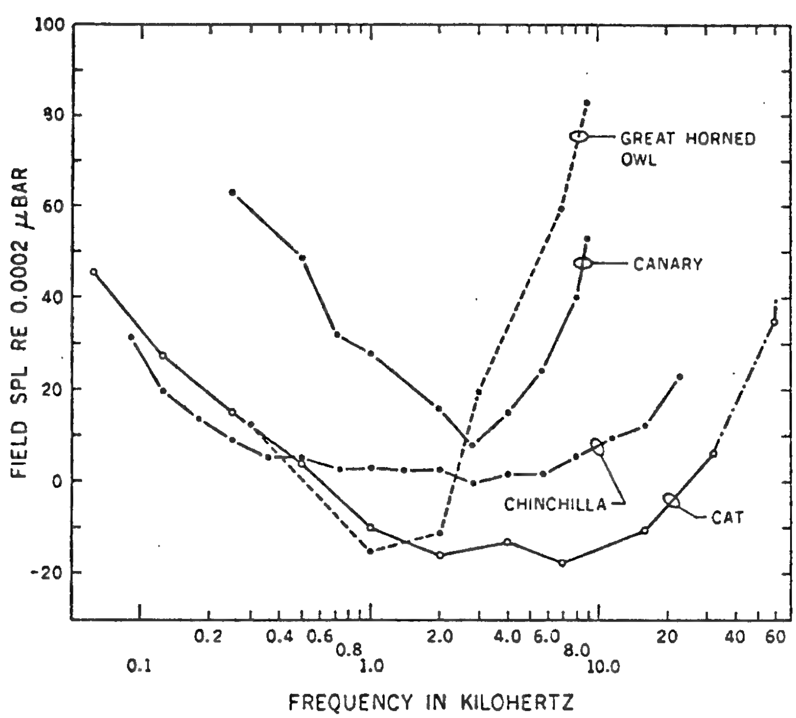


FIGURE 2: Auditory threshold curve in man

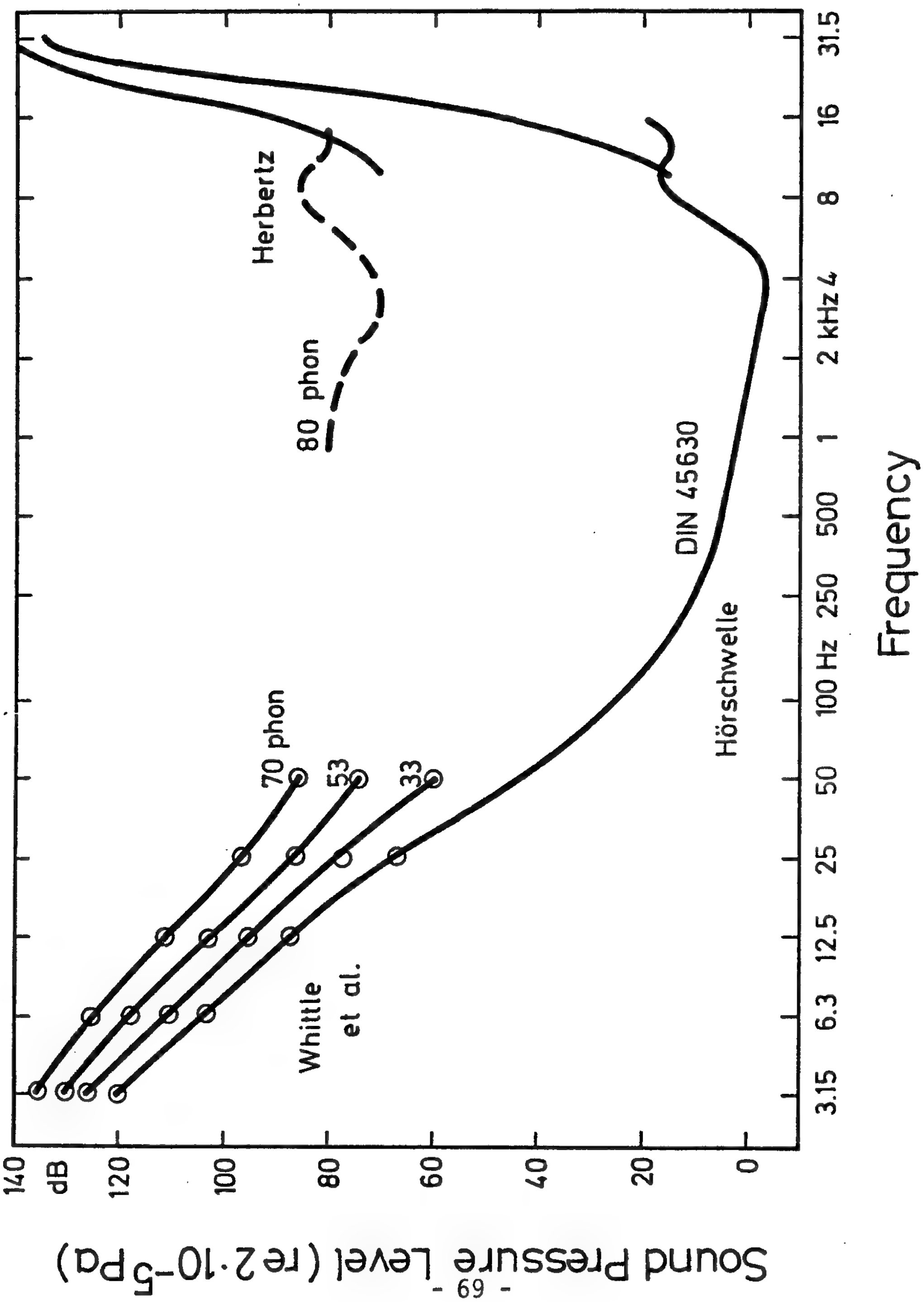


FIGURE 3: Hearing threshold in gulls (●) pigeons (♦) and gunea fowls (O) determined by electrophysiology

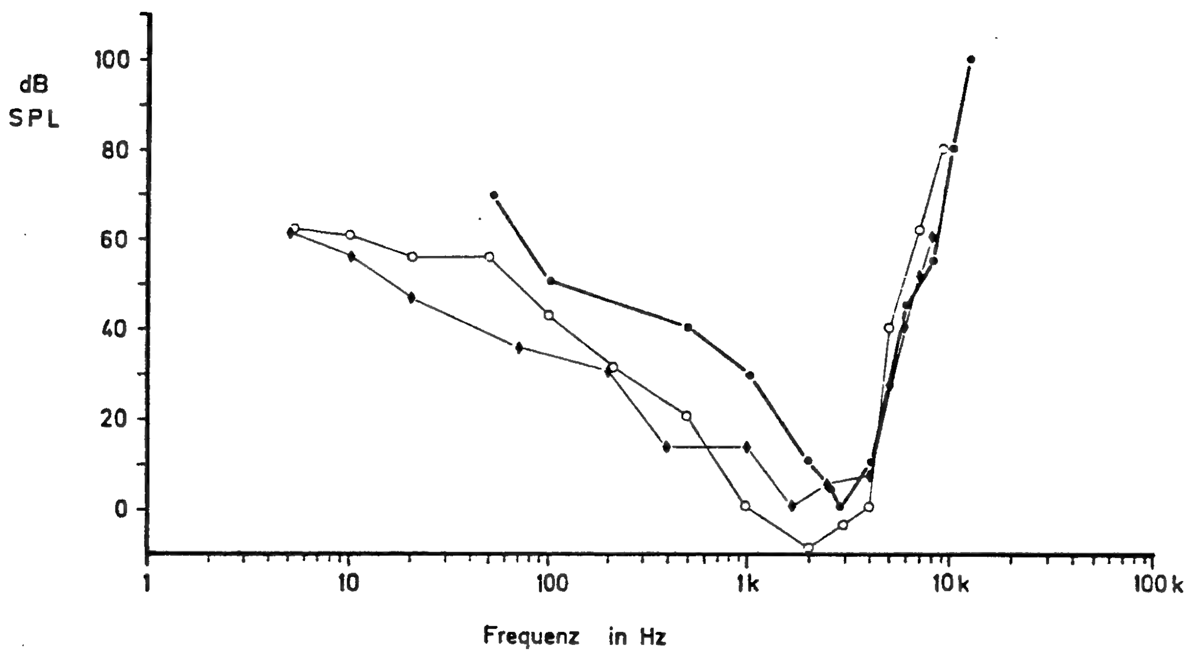


FIGURE 4: Reaction level of gulls for tones at 100 dB sound pressure level

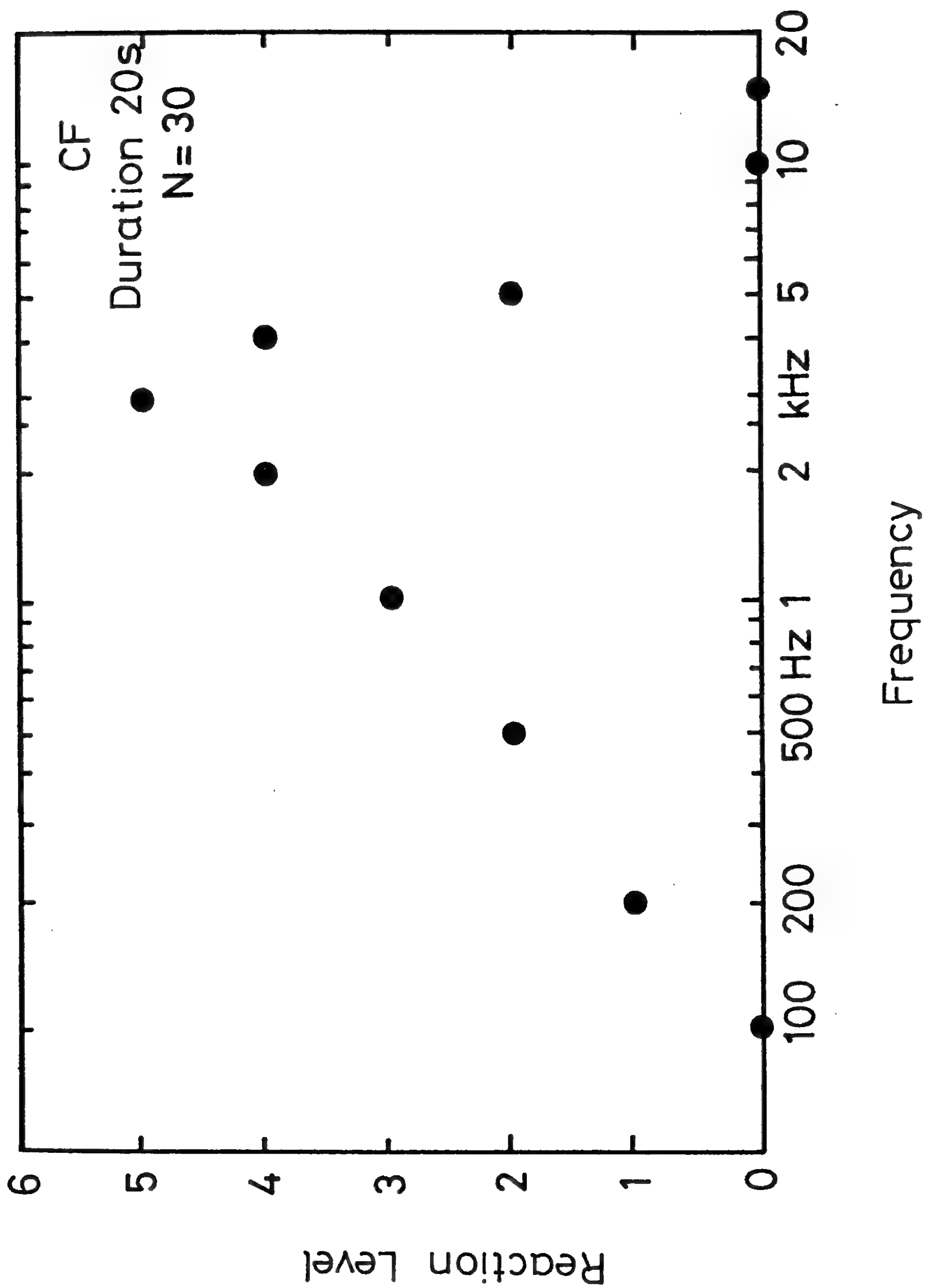
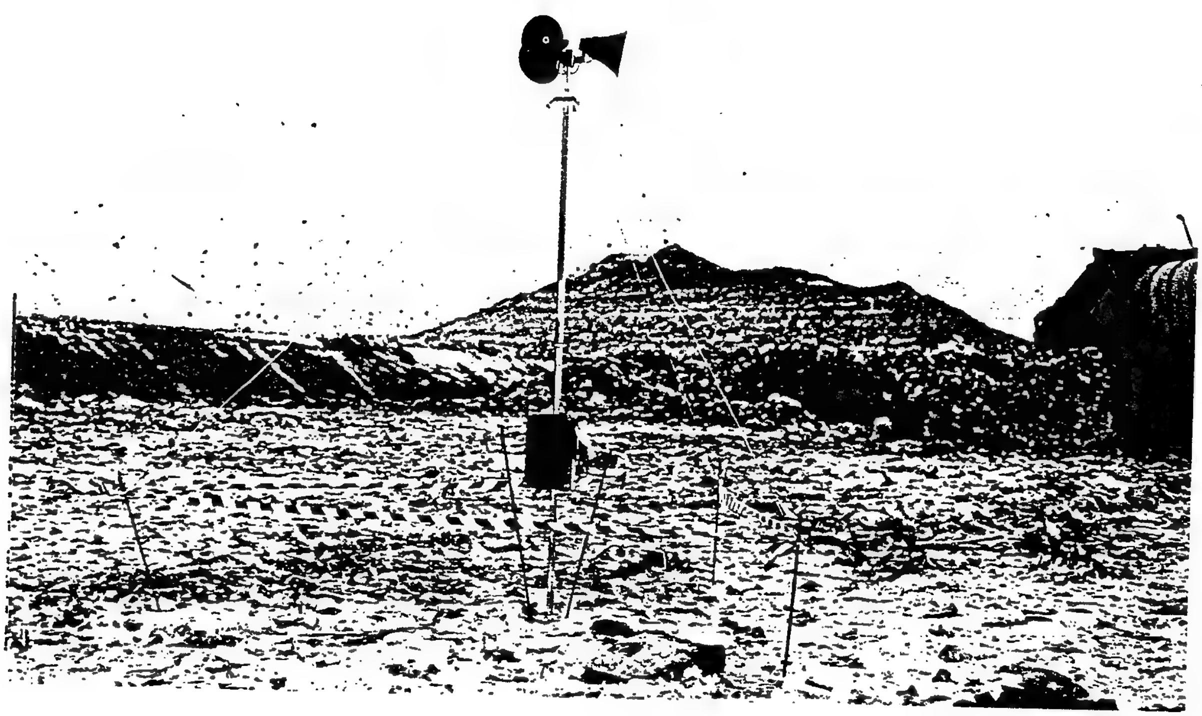
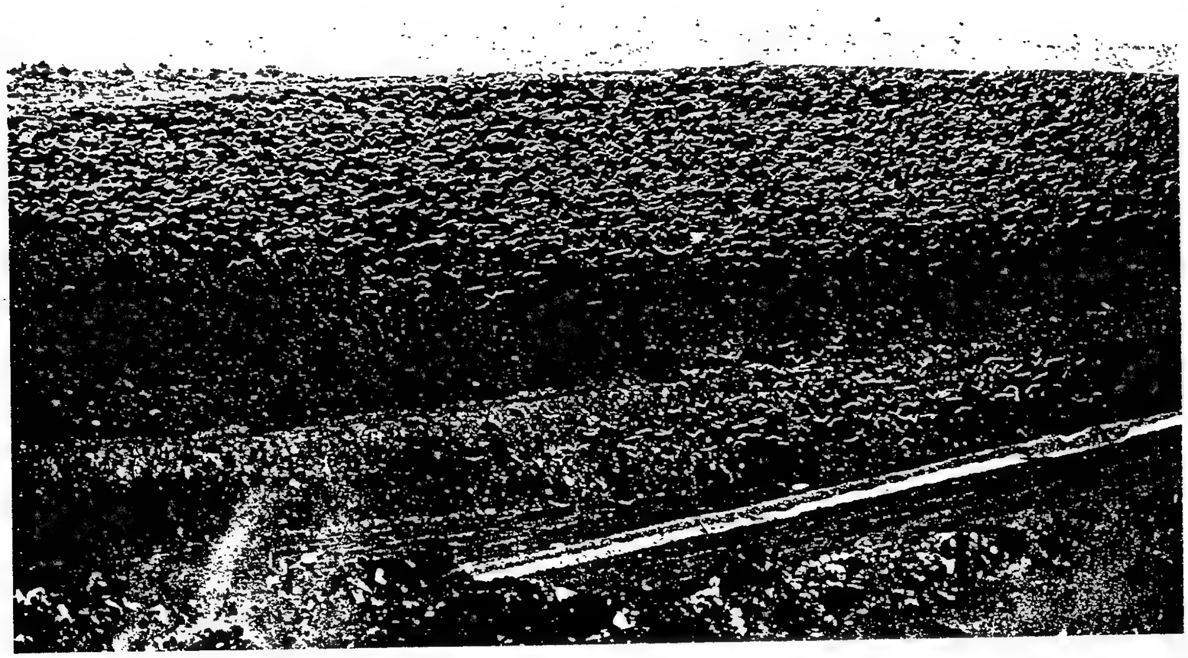


FIGURE 5: Electroacoustic bird scaring device



<u>FIGURE 6:</u> Effect of scaring sounds on roosting gulls. Pictures taken before and short time after insonification



BIRD STRIKE COMMITTEE EUROPE

Copenhagan, May 1986
BSCE 18/WP 4

ADF616044

SERIOUS BIRD STRIKES TO CIVIL AIRCRAFT 1984 & 1985

John Thorpe - UK Civil Aviation Authority
Safety Data & Analysis Unit

SUMMARY

The paper contains a sample of detailed histories of accidents and more serious incidents (e.g. double engine ingestion, holed airframe, fire, uncontained engine failure) for the years 1984 and 1985. The paper is divided into three groups:

- transport aircraft over 5,700 kg and executive jets
- aeroplanes of 5,700 kg and below
- all helicopters

No attempt has been made to analyse the information although it is apparent that for transport aircraft the critical area is engines (20 out of 36 incidents in the paper) and for light aeroplanes and helicopters the windshield may be the critical area. As far as is known, during this period there have not been any hull losses.

The Author would welcome any new or additional information as it currently relies heavily on UK and ICAO information.

SERIOUS BIRD STRIKES TO CIVIL AIRCRAFT 1984/85

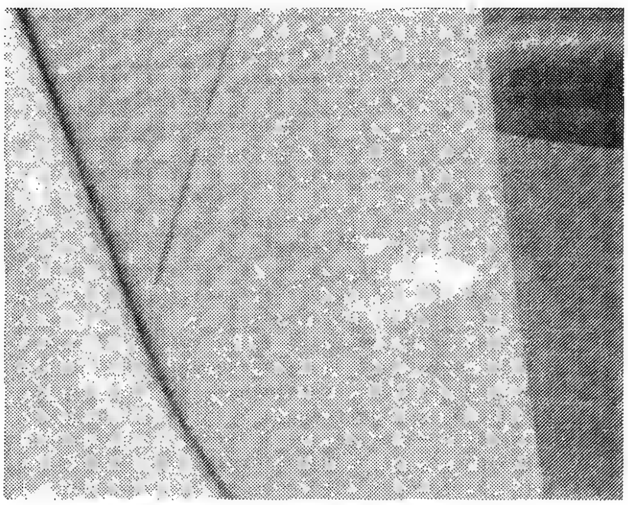
AEROPLANES OVER 5700 KG AND EXECUTIVE JETS

Date	Aircraft	Regn	Operator	Location	Total Aboard	Injury to Occupants
30.01.84*	Concorde	G-BOAD	British Airways	London Heathrow	-	Nil

After gear retraction one of the hydraulic system contents fell to zero. Fuel jettisoned for return. After landing a second hydraulic system contents fell to a low level. Found a bird (believed gull) had impacted the rear of the landing gear bay and had punctured a structural diaphragm damaging hydraulic couplings. This occurred during 15 seconds doors are open for gear retraction. A debris guard has now been added. No part of the other system was damaged. (Source - UK Reporting)

Date	Aircraft	Regn	Operator	Location	Total Aboard	Injury to Occupants
11.02.84*	B707	G-AXGX	British Airways	Karachi, Pakistan	-	Nil

AT 2500 ft accelerating to 250 kts a large bird struck the wing leading edge. An 18" x 12" hole was made. Continued at 250 kt at 16000 ft to Doha. No. 2 generator tripped due to slight cable damage. Bird was vulture, either White-backed or Griffon (weights 5.3 kg or 8 kg). (Source - UK Reporting)



Date	Aircraft	Regn	Operator	Location	Total Aboard	Injury to Occupants
18.03.84*	B747	G-BDXJ	British Airways	-	-	Nil

Pre-flight inspection at Nairobi revealed a birdstrike had removed the lower skin from wing mid-flap. Area of damage about 12" x 3". (Source - UK Reporting)

Date	Aircraft	Regn	Operator	Location	Total Aboard	Injury to Occupants
22.03.84	B737	5N-ANY	Nigerian Airways	Port Harcourt, Nigeria	-	Nil

During the landing roll a landing light was broken and a large hole made in the fuselage. (Source - ICAO IBIS)

Date	Aircraft	Regn	Operator	Location	Total Aboard	Injury to Occupants
26.03.84*	B747 (JT9D)	-	-	Delhi, India	-	Nil

Descending through 2500 ft bird struck engine 2. Inlet nose cone had large hole and inlet cowl inner skin holed. Slight damage to two fan blades. (Source - Lloyds)

Date	Aircraft	Regn	Operator	Location	Total Aboard	Injury to Occupants
28.03.84	Aerospace Guppy	F-BPPA	Airbus Industry	Toulouse, France	-	Nil

At about 50 ft and 127 kts a large flock of Black-headed gulls (Larus ridibundus) were struck. After an engine (T34) was shutdown the aircraft returned. The windshield was split, nose dented and engine 1 propeller damaged. (Source - ICAO IBIS)

Date	Aircraft	Regn	Operator	Location	Total Aboard	Injury to Occupants
19.04.84*	Boeing 747SP (JT9D)	N-	TWA	JFK New York	-	Nil

Birdstrike on landing, shutdown engine. Found nose spinner shattered, tail cone liberated, with damage to nose cowl, fan blades and fan case.

Date	Aircraft	Regn	Operator	Location	Total Aboard	Injury to Occupants
29.04.84	B737	VT-EAJ	Indian Airlines	Patra, India	-	Nil

While passing 160 ft at 170 kts in the climb a single eagle struck the wing leading edge. The rear side partition wall cracked and the flap hinge was damaged. (Source - ICAO IBIS)

* Were in BSCE 17 (Rome) WP 27

08.05.84	L1011	D-AERP	LTU .	Palma, Majorca	-	Nil

A precautionary landing was made with one engine shutdown after gulls were struck at 140 kts during the take off run. Engine 1 seized, engine 2 had cowling damage, engine 3 was also struck. (Source - ICAO IBIS)

07.06.84	B737	C-GOPW	Air Canada	Edmonton, Canada	-	Nil

At about 160 kts during the take off a flock of Herring gulls (Larus argentatus) were struck. The radome engine 2, light and windshield were damaged. The aircraft returned. (Source - ICAO IBIS)

22.06.84	DC10	TU-TAN	Air Afrique	Paris CDG	-	Nil

Fuel was jettisonned and a precautionary landing made after Herring gulls (Larus argentatus) struck engines 2 and 3. Four fan blades were damaged on engine 2 and 34 on engine 3. (Source - ICAO IBIS)

01.08.84	A310	G-BKWU	British Caledonian	Yundum, Gambia	-	Nil

During the take off run two birds struck the nose, one of which was in the area of the Captain's pitot. No 1 flight augmentation computer (i.e. speeds, pitch trim and yaw damper) were lost. (Source - UK Reporting System)

08.08.84	B737	G-DGDP	Monarch	Corfu, Greece	-	Nil

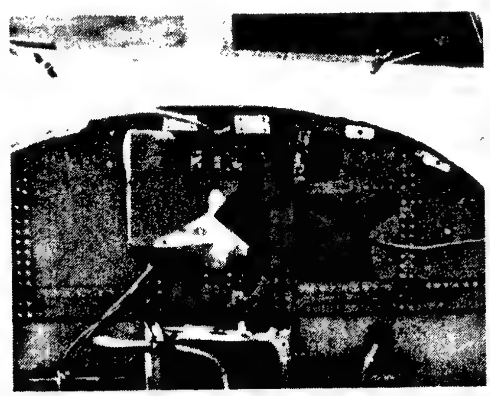
At 142 kts on rotation the air/ground sense line on the RH landing gear was damaged by birds. (Source - UK Reporting System)

19.08.84	B747 (JT9D)	N221GF	Swissair	Zurich, Switzerland	-	Nil

Take off was abandoned at 154 kts after pigeons were ingested in engines 2 and 3. (Source - ICAO IBIS)

19.09.84	B737	ZS-SBP	SAA	Nr Kimberley, South Africa	40	Nil

While climbing through 7,000 ft at 280 kts the aircraft struck a Great Blue Heron (Ardea herodias) weight 2.7 kg. The bird penetrated the cockpit forward bulkhead on the Captains side knocking out the altimeters. The pressurisation system went from automatic to standby but maintained pressure. There were no injuries but the Captain was covered in blood and aircraft pieces. Noise hampered cockpit communication and the smell was so bad the crew used oxygen. The co-pilot had sighted a pair of birds slightly above the aircraft, but the bird folded its wings and struck the aircraft. (Source - Lloyds and FSF)



22.09.84	B737	G-AXNA	Britannia	Manchester, UK		Nil

The aircraft struck a flock of Black-headed gulls, there was a bang and the aircraft yawed. Take off was abandoned at V1 of 143 kts. Full reverse was used, runway was wet. The gear fusible plugs blew and brakes seized. Feathers in both engines, but no damage. (Source - UK Reporting)

29.09.84	A300B	F-BUAE	Air Inter	Marseilles, France	-	Nil

At 130 kts a large flock of Herring gulls were struck. The take off was abandoned. The wing leading edge was holed, and six fan blades were damaged in both engines 1 and 2. (Source - ICAO IBIS System)

07.10.84	B737	VT-EHE	Indian Airlines	Calcutta, India	-	Nil

During the approach a large vulture pierced the top of the windshield. The cockpit was covered in broken glass and remains. (Source - ICAO IBIS)

23.10.84	B737	G-BGDK	British Airways	Berlin Tegel	98	Nil

Just after rotation birds were struck. All engine indications were normal. Damage found on arrival to engine 1 fan blades (one bent, two shingled) and shingled blades on engine 2. Flaps also dented. (Source - UK Reporting System)

24.10.84	B727	C-GAAG	-	Nr Winnipeg, Canada	-	Nil

While climbing through 1600 ft at 190 kts a flock of geese damaged the radome, engine 3, wing, tail, lights and penetrated the airframe. Engine 3 was shutdown and windshield vision was obscured. (Source - ICAO IBIS)

01.11.84	Short SD330	N-		Peoria, USA	-	Nil

On the approach the right hand side window was shattered and parts of bird and window struck the first officer. He was able to perform his duties, but was bruised. The aircraft RH inboard exhaust stack was also damaged. (Source - FAA)

06.11.84	B737	HR-SHA	Sahsa	Lasham, UK	7	Nil

The aircraft had been undergoing maintenance at the unlicenced aerodrome. A vehicle was used to check that the runway was clear of birds. At rotation the captain saw a large flock of lapwings in the aircraft's flight path, but hoped to fly over them. Loud bangs were heard and both engines appeared to lose power. A passenger saw 2 birds enter No 2 engine, severe vibration ensued and the Captain reduced power at 2000 ft, as engine 2 EPR etc was low. About 7 minutes after take off the engine intake cowling detached and fell in a field. The engine was shutdown, and a single engined landing made at Hurn. 18 dead lapwings were found on the runway. No 2 engine compressor was badly damaged, vibration causing cowling detachment. No 1 engine was undamaged. (Source - UK AB Bulletin)

30.11.84	B737	G-AZNZ	Britannia	Ibiza, Spain	-	Nil

At 200 ft and 162 kts on a night take off the radome was holed by a birdstrike. The radar worked normally during the flight. (Source - UK Reporting System)

06.12.84	N262	F-BPNS	DGAC	St Yan, France	-	Nil

While climbing through 150 ft at 110 kts a flock of rooks (Corvus frugilegus) struck the windshield, nose propellers, wing and tail. The wing leading edge was holed. (Source - ICAO IBIS)

27.12.84	B747	G-AWNL	British Airways	Over North London	172	Nil

While climbing through 4000 ft at 260 kts a loud bang was heard. The steward reported that cabin window 3L was cracked and blood and remains had splattered two first class passengers. The aircraft was de-pressurised, 10,000 kg of fuel jettisoned and the aircraft returned. The birds were identified as Lapwings (Venellus vanellus), flying at night. Seven birds struck the aircraft, a large dent being left in the tail plane leading edge. The impact on the window forced the outer pane against the inner pane which cracked and broke against the window retaining clips. (Source - UK Reporting)

11.01.85	B737	G-BGDO	British Airways	Aberdeen, UK	120	Nil

During the approach at about 200 ft and 130 kts the aircraft passed through a flock of Lapwings which rose from fields near the airport. Both engines, radome, windscreen, wings and fuselage were struck. Four fan blades were shingled in engine 1 and one blade shingled in engine 2. (Source - UK Reporting System)

28.01.85	B737	G-BGDE	British Airways	Cork, Ireland	-	Nil

Gulls ingested in both engines at 120 kts on take off. Smell from air conditioning. Flight continued on one system. Radome, wing and landing gear struck. Engine 1 had shingled fan blades, engine change. (Source - UK Reporting System)

17.02.85	B737	G-BFVA	Britannia	Malaga, Spain	-	Nil

On landing, the aircraft struck a partridge damaging the air/ground sensor on the RH main gear leg. This caused the air conditioning and electrical system to malfunction. The aircraft was ferried to base. (Source - UK Reporting)

16.04.85	B737	-	Far Eastern Transport	Taipei, Taiwan	93	Nil

The aircraft skidded off the runway during take off after a bird struck the right hand engine. (Source - Lloyds)

28.07.85	B747 (CF6)	-	-	-	-	Nil

Unknown bird species ingested by engine 2 during take off, which was abandoned. All fan blades badly damaged, N1 sensor struck by large piece of fan blade which exited through fan cowl. Exhaust centrebody departed. Trailing edge flaps damaged by piece of blade. (Source - Engine Manufacturer)

29.07.85	B747 (RB211)	-	Air New Zealand	Christchurch, New Zealand	370	Nil

At rotation on take off for Melbourne birds were ingested in two engines. They were shut down shortly afterwards, the aircraft climbed on three engines, before a second engine was throttled back. Fuel was jettisoned prior to landing. Two engines were removed, one having fan blade and duct damage. (Source - Aviation Week)

09.08.85	Cessna Citation	OY-CEV	Falck Air	Dusseldorf, Germany	-	Nil

The aircraft ingested a flock of Lapwings in both engines at about 150 ft on take off. One fan blade was damaged. (Source - Danish Reporting System)

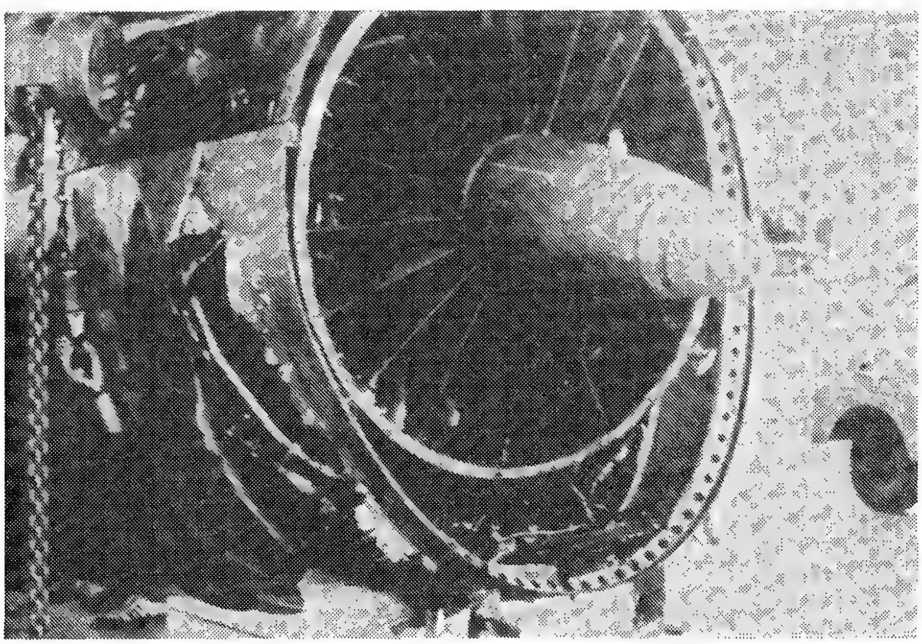
04.09.85	DC10-30	-	-	Rio de Janeiro, Brazil	-	Nil

Engine 3 ingested a large bird on take off, severe vibration caused shutdown. Fuel was jettisoned before landing. A hot brake fire was extinguished on landing. Heavy fan damage with four broken blades, and minor aircraft damage. Inlet cowl and both fan cowl doors separated and were on the runway. Bird may be Heron (3-4 kg) which feed near airport runway departure area. (Source - Engine Manufacturer)

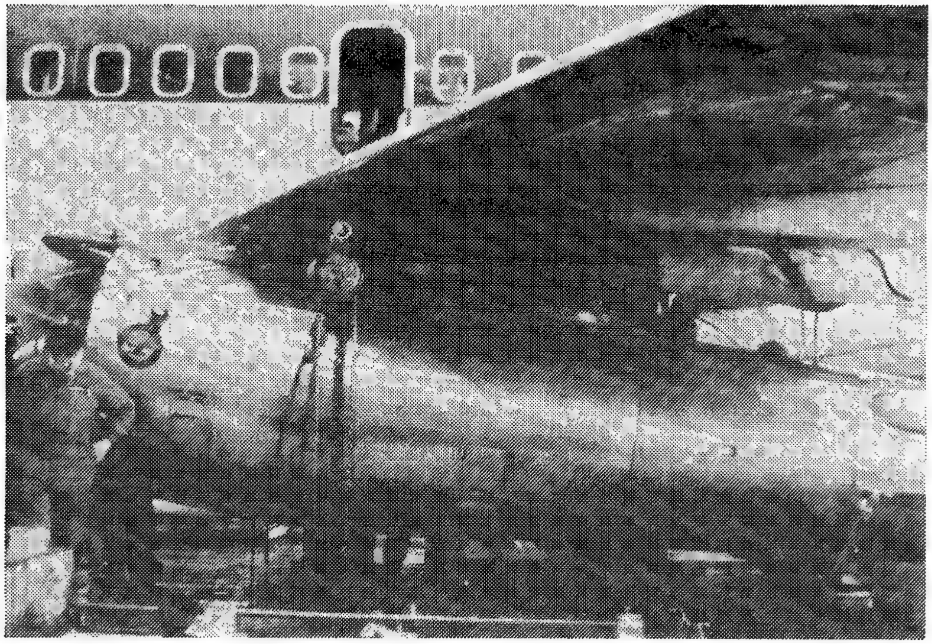
07.12.85	B737	EI-ASA	Aer Lingus	Dublin, Ireland	-	Nil

At 50 ft after take off a flock of gulls were struck, No 1 engine surged and the throttle lever slammed rearwards by itself passed the detent and unlocked the thrust reverser. The engine was shutdown, and a single engined landing made.

Ground inspection revealed No 1 engine nose cowl was missing, eight first stage fan blades were liberated and the inlet case and both front and rear fan containment cases had major penetrations. Two of the three engine mount bolts were fractured and the engine was only attached by the front left cone bolt and flexible hydraulic lines at the rear of the engine. Bird remains were found in the fan discharge duct, LH main gear well and outboard trailing edge flaps of the RH wing. Three bird carcasses were found on the runway.



Birds were Black-headed gulls (which weighed 275 gm to 350 gm) only one bird entered the engine striking No 20 fan blade 2" from its root; it broke off initiating the engine failure. Debris exited at the 8 o'clock position and broke the outer pane of a window as well as entering No 2 engine causing blade and stator damage. The airline stated the cost was $1.25 million. (Source - Engine Manufacturer and Operator)



16.12.85	B737	G-BGDP	British Airways	Malta	-	Nil

During landing flare air/ground sensor cable was damaged by flock of doves. (Source - UK Reporting System)

30.12.85	B737	ZS-SBO	SAA	East London, South Africa	-	Nil

The aircraft returned after a Blue crane (Anthropoides Paradisea) weight 3.5 kg was ingested in engine 1. Majority of fan blades were broken or liberated and several bolts were broken at 'B' flange. The oil tank was detached from its mount. (Source - Engine Manufacturer and Lloyds)

AEROPLANES OF 5700 KG AND BELOW

Date	Aircraft	Regn	Location	Total Aboard	Injury to Occupants
07.04.84*	Cessna 421	G-JTIE	Oxford, UK	-	Nil
	Flock of pigeons rose from runway as aircraft rotated at 100 kts. Multiple strikes, both engines had birds sticking out of vents. Right hand propeller control seized and engine sounded rough. Returned. Found right hand engine cowling cracked. (Source - UK Reporting)				
23.03.84*	Turbo Thrush	-	Cayman Islands	1	Nil
	Garrett engine flamed out after birds were ingested resulting in a night forced landing. The landing gear was badly damaged. (Source - CAA AD)				
01.06.84*	DHC6	G-BIEM	Stornoway UK	-	Nil
	At 500 ft, 95 kts one of three Great-black-backed gulls (Larus marinus) struck the wing leading edge causing an 18" x 10" hole, and structural damage. (Source - UK Reporting)				
01.06.84	Beech 90	TF-DCA	Isafjordur, Iceland	-	Nil
	Just prior to touch down at about 90 kts, a bird struck the wing flaps, breaking the flap spar. (Source - ICAO IBIS)				
17.07.84	MU2	TF-JMC	Akureyri, Iceland	-	Nil
	During the landing roll one Black-headed gull was ingested in engine 2 (a TPE 331). The engine flamed out and caught fire. The aircraft was out of service for 10 days. (Source - ICAO IBIS)				
26.07.84	Robin 2+2	-	Nr Quiberam, France	-	Nil
	While flying at 1200 ft at 120 kts the windshield was broken by an unknown bird. A precautionary landing was made. (Source - ICAO IBIS)				
11.09.84	EMB110	Bandeirante	Hamilton, New Zealand	-	Nil
	AT 50 ft just before landing, the windshield was damaged by a single duck. (Source - ICAO IBIS)				
15.10.84	Piper PA31 Navajo	-	200 miles N Saskatoon, Canada	-	Nil
	While cruising at 2000 ft at 180 kts a number of geese (between 2 and 10) were struck. The RH windshield was shattered leaving a 6" x 12" hole. There was extensive damage to the cockpit ceiling area. (Source - ICAO IBIS)				
03.07.85	Cessna F152	G-BKGW	Sywell, UK	1	Nil
	The aircraft was being flown by a student pilot. He was returning to Sywell on completion of a qualifying cross country flight. The pilot executed two go arounds due to the presence of a flock of birds on the landing runway 03. Following advice from air traffic control that the birds would move out of the way of his landing run the pilot began a third and final approach. The pilot states that immediately prior to touch down the aircraft was struck by birds on the windscreen, wing and strut. He also states that he was distracted as the flock of birds rose around him causing him to land his aircraft heavily. It bounced some 10 to 15 feet and landed heavily again on the nosewheel which collapsed, permitting the propeller to strike the ground. The birds were identified as rooks and some remains were found near to where the aircraft came to rest. Bird scaring devices, in the form of explosive charges connected to slow burning rope fuses, were in operation at the airfield. (Source - UK AIB Bulletin)				
16.10.85	Cessna 150	G-BCKU	Perth, UK	1	Nil
	A Greylag goose (Anser anser) 3.3 kg struck the pitot tube tearing the wing skin. The incident was at 600 ft and 70 kts. (Source - UK Reporting)				

* Were in BSCE 17 (Rome) WP 27

HELICOPTERS

Date	Helicopter	Regn	Operator	Location	Total Aboard	Injury to Occupants
30.04.84	AS350	F-ODGE	-	New Caledonia	-	Nil
	While flying at 120 kts at 600 ft the fuselage was holed by an unknown bird. A precautionary landing was made. (Source - ICAO IBIS)					
10.06.84	Bell 206	SE-HPL	-	En Route	-	Nil
	While flying at 500 ft at 100 kts between Svartso and Lovstad a bird penetrated the lower front windshield. (Source - ICA IBIS)					
06.11.84	Bell 206	G-BBBM	CB Helicopters	Nr Leavesden, UK	-	Nil
	In cruise at 600 ft and 100 kts a Mallard was seen just in front of the helicopter. It shattered the windscreen and struck the pilot's chest. (Source - UK Reporting)					

BSCE 18/WP 5

Copenhagen May 1986

ADF616045

THE USE OF RADAR DATA FOR BIRD STRIKE PREVENTION IN GERMANY

J. Becker

German Military Geophysical Office

In the Federal Republic of Germany military and civil radar stations are performing observations of bird movements by polaroid pictures or movie pictures of the radar scope. The polaroid pictures give information of actual migratory movements of birds, and are used for bird strike warnings (birdtam). The observations by movie film are used for the investigation of seasonal and spatial variations of bird movements as well as for the correlation between weather and bird migration. The knowledge of factors influencing the timing and amount of bird migration is fundamental to the bird strike risk forecast issued by the German Military Geophysical Office.

1. INTRODUCTION

The control of birds over large expanses of airspace in which aircraft movements and bird activities overlap needs a dense observation network. Information about migrating birds at lower altitudes can be obtained by visual observations. For larger areas and heights above 1000 ft GND radar observations are necessary. A problem of radar observation is the varying quality in different areas based on the radar coverage, the used type of indicator and video processing. In the Federal Republic of Germany military and civil radar stations are performing observations of bird movements by polaroid pictures or 16 mm-film pictures of the radar scope. The results are used in different ways for the warning and forecast system of the Federal Armed Forces.

2. BIRD MOVEMENT DATA OBTAINED BY MILITARY RADAR STATIONS

The high-powered air defense radar stations of the German Air Force observe continuously migratory movements of birds. For the identification and determination of bird echoes polaroid pictures are taken from the radar scope with an exposure time of 12+3 minutes, with an interruption of 2 minutes, every three hours between dawn and dusk. In the morning and during periods with bird migration the time between two pictures is shortened to one hour. The observations are not carried out on weekends.

Disadvantages of the photographic system are a loss of information in the video processing as well as the identification and determination of bird echoes by different persons. Nevertheless a well-trained radar staff is able to discriminate echoes caused by bird movements from other targets and clutter echoes. The bird intensity according to the international 0 to 8 scale can be determined with an accuracy of $\pm$ 1 scale unit. This is sufficient for bird strike warnings (birdtam), because the bird strike hazard indicated by the bird intensity is always an average number, and the density of bird movements is varying within the relatively large area covered by birdtam. The electronic counting system for radar echoes can avoid many disadvantages of the photographic system, but it is difficult to estimate how significant the bird intensity counted in a reference area is for the entire area covered by the birdtam.

After the evaluation of the radar photo the following data are transmitted to the Geophysical Information Offices of the radar stations or of nearby air bases: radar site, time of observation, bird intensity, GEOREF-areas covered by bird echoes, and the direction of bird migration. There is generally a lack of detailed information concerning the altitude of bird migration. Therefore standard heights must be used in the birdtam. The observation message is transmitted via teleprinter to the Forecast Centre of the German Military Geophysical Office, where the message is immediately transformed into a birdwarning message (birdtam) according to formalized procedures. The birdtam are distributed to all military aerodromes as well as to foreign air traffic control centres via EDCCIV (see figure 1).

Additional sources of information concerning bird migration are some GCA- and Wx-radar equipment of aerodromes, pilot reports and visual observations. Foreign birdtam and bird warning messages are transformed into the format of NOTAM class 1 used in the German birdtam. A standardization of bird warning messages and birdtam/bird strike warnings will occur in 1986. Nevertheless differences of bird intensities and warning heights will still occur because of the different radar equipment, and the different procedures of evaluation. The main purpose of all observations by military radar stations is the immediate warning of bird strike hazards to the flying units.

3. BIRD MOVEMENT DATA OBTAINED BY CIVIL RADAR STATIONS

During the last years only a small part of the entire passage of migratory birds could be observed by the German military radar stations due to the priority of other tasks or technical problems. Therefore the data obtained are insufficient for a detailed analysis of bird migration. The continuous observations necessary for this purpose are performed by 3 civil L-Band radar stations. In contrast to the military observations the radar scope (PPI) is recorded by 16 mm-cine-film. In 1972 and 1973 the radar scope was filmed by the timelapse technique only during spring and fall. In 1975 the switching mechanism was modified to work at two photographs/hour, each with an exposure time of 15 minutes. During 3 months only 30 m film material are necessary for that purpose. Therefore the radar scope can be filmed continuously throughout the year. Nevertheless some interruptions occur by the change of the film or by the maintenance of the equipment. The owner of the movies is the German Bird Strike Committee (DAVVL). The evaluation of the total sequences enables the discrimination of bird echoes from other clutter. The observation of single pictures enables the determination of bird intensities and of flight directions.

The recordings by movie film cannot be used for actual bird strike warnings, but they are the most complete existing data of large-scale bird movements at altitudes above 600 ft GND. Therefore the films are important for the investigation of seasonal and spatial variations of bird movements as well as for the correlation between weather and bird migration. The figures 2 - 4 show the seasonal variation of maximum bird intensities detected by the radar station at Munich during the years 1981 - 1983, using mean intervals of 2 weeks to avoid variations of bird intensities due to days with insufficient observation. The intensity of bird migration was estimated according to the internationsl 0 - 8 scale.

During Spring higher bird intensities were registered than during fall,depending on generally greater flight altitudes,due to favourable air currents in spring. At night the migratory movements reached generally higher intensities than in the daytime. From the end of March to mid of May as well as from September to mid October night migration dominates in relation to daytime migration. The maximum intensities of bird migration at high altitudes and the busiest times of general bird migration correspond to each other. High and moderate intensities of bird migration do not continue longer than 3 days/nights in succession. The example of fall migration in 1983 (figure 5) shows the relatively quick change between days with high, medium or light bird intensities. The intensities and directions of the bird movements are influenced by the weather conditions of the departure areas as well as the weather enroute. Moderate bird movement intensities were reached for the first time on the 13th of October after the passage of a cold front, and under high pressure influence over Central Europe. Two days with moderate to high bird movement intensities occurred on the 22nd and 23rd of October after the presence of good flight weather over southern Scandinavia, Poland and East Germany on October 21st. Similar weather conditions with dropping temperatures caused moderate to high bird movement intensities on October 29th. The highest bird movement intensities of fall migration occurred on November 2nd and 12th, at high pressure influence and weak northeasterly winds over the departure areas CSSR/Poland as well as over Bavaria.

The correlations between bird movement intensities and weather factors are fundamental to the birdstrike risk forecast. This forecast issued daily by the German Military Geophysical Office considers the phenology of bird migration and vegetation as well as the weather conditions of the departure and passage areas of bird migration. The weather influence has been related to four parameters: flight weather (especially precipitation and visibility). Change of the temperature during 24 hours, wind direction, and wind speed. These conditions are determined from weather analysis and forecast data, and combined to a weather factor

modifying the mean bird strike intensity expected in accordance to the season and the actual bird migration 'till that date. The connections between the birdtam and the bird strike risk forecast system are shown in figure 6. As birdtam are based on actual observations of large-scale bird migration, and the bird strike risk forecast provides information on the average bird strike risk over a relatively large area, mostly the geographical forecast areas A1 to A4 (see figure 7), the two factors concerning bird strike hazards do not correspond in detail. The purpose of future work must be a denser network of data concerning migratory movements of birds as well as sophisticated computer models for the relation between bird movement intensities and predictable biological and meteorological factors. Also in the future radar observations of bird movements will be the main source to get fundamental data for the procedures necessary for the prevention of bird strikes.

FIGURE 1 Survey of the German bird strike warning system

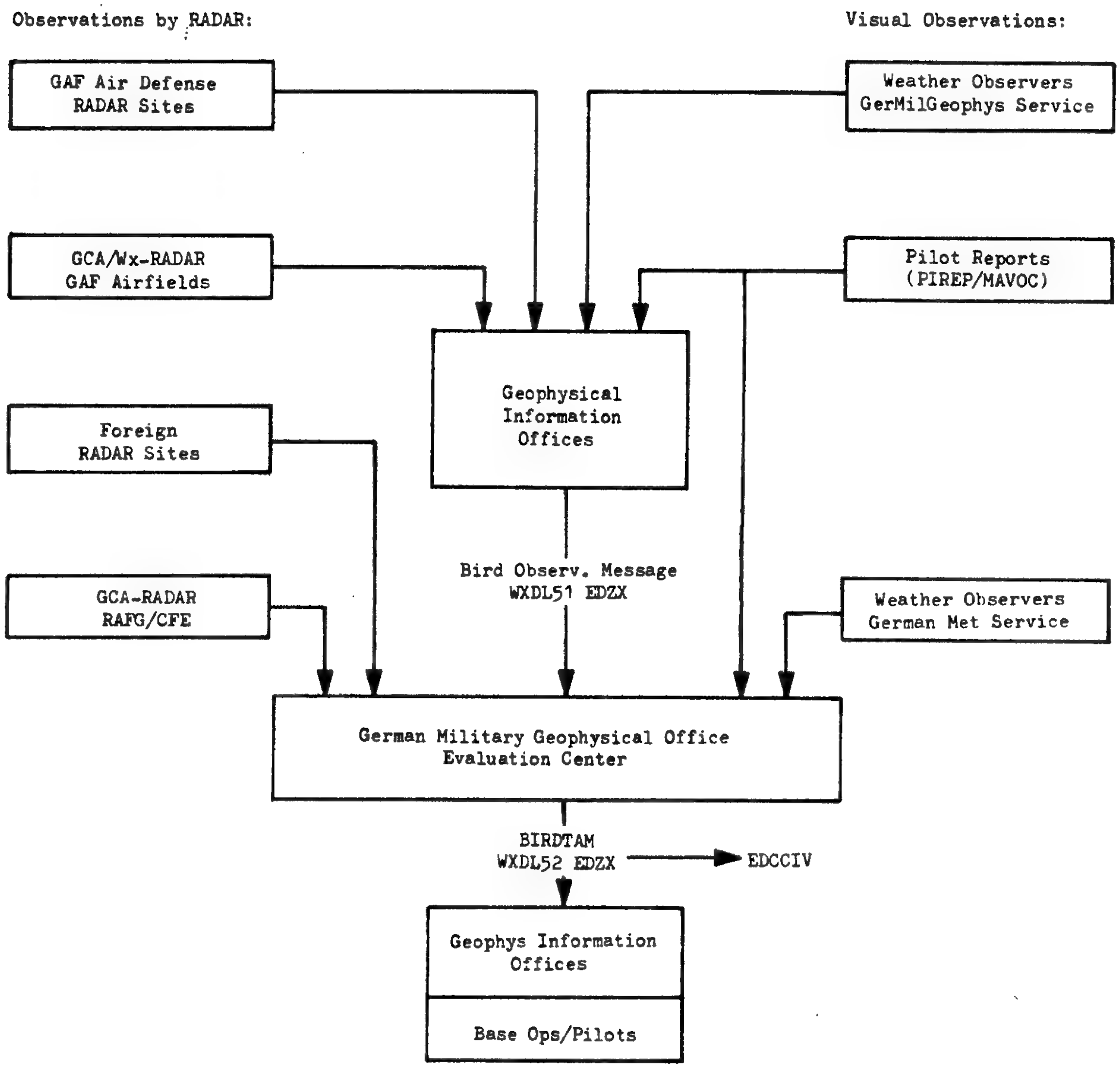


FIGURE 2 Seasonal variation of the average maxima of daytime bird movement intensities over Bavaria from 1981 to 1983

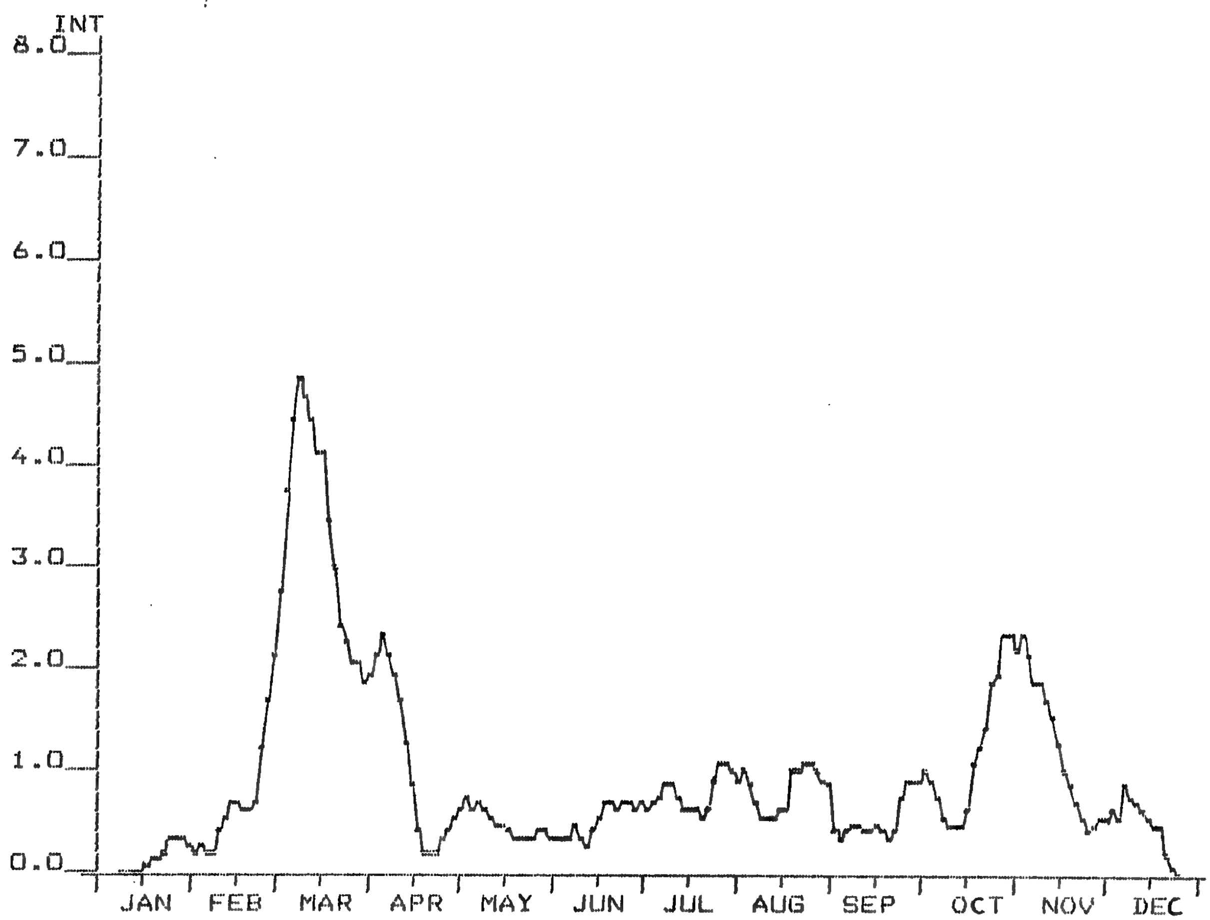


FIGURE 3 Seasonal variation of the average maxima of birdmovement intensities at night over Bavaria from 1981 to 1983

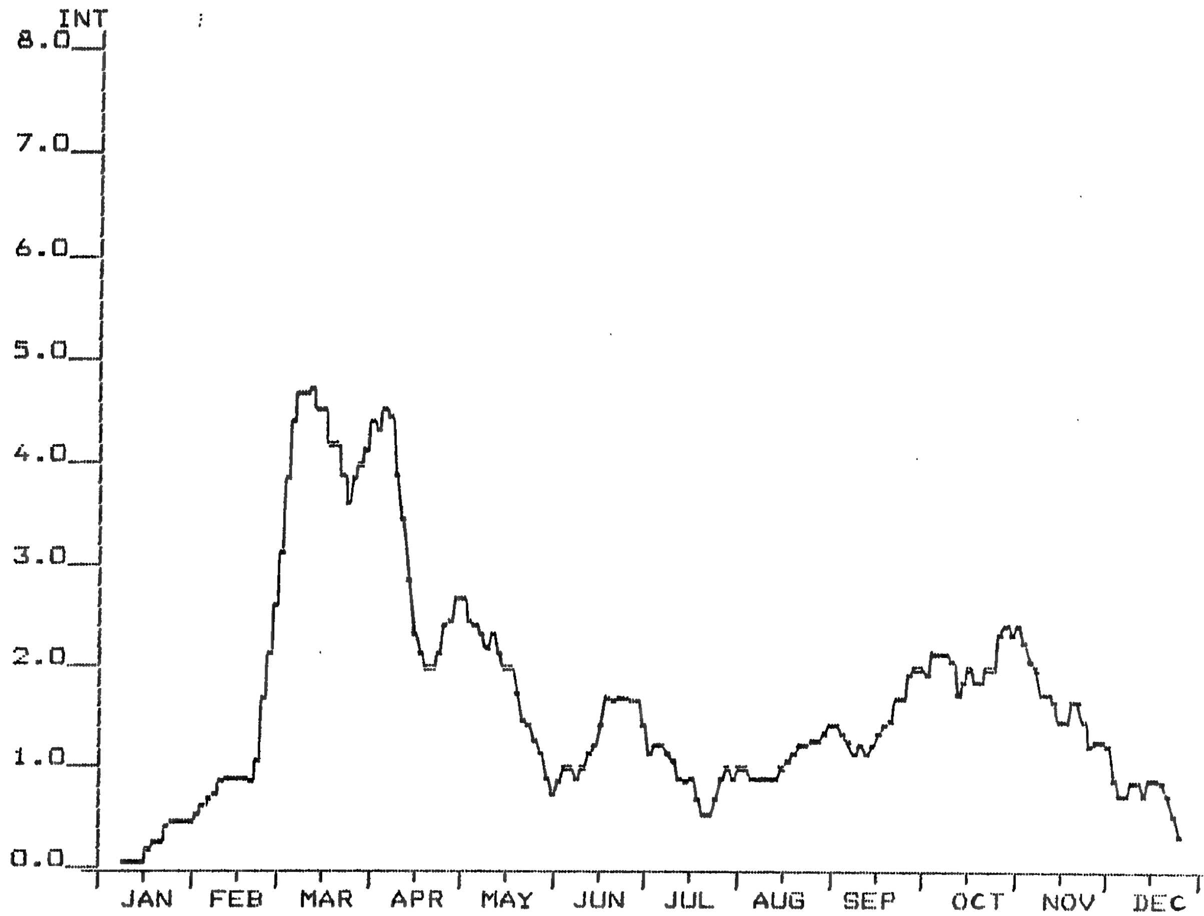


FIGURE 4 Seasonal variation of the average maxima of bird movement intensities at high altitudes over Bavaria from 1981 to 1983

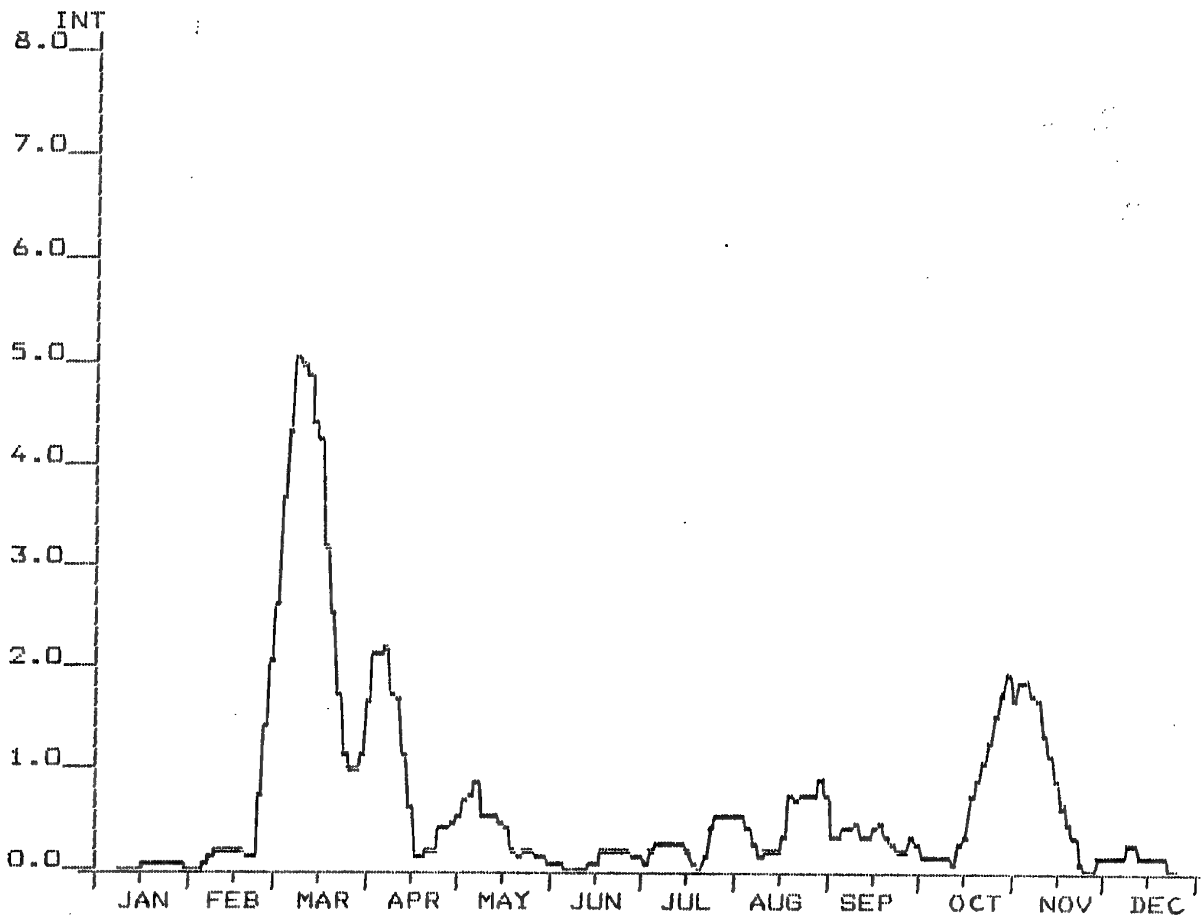


FIGURE 5 Daily maximum bird movement intensities over Bavaria from 15 September to 15 November 1983

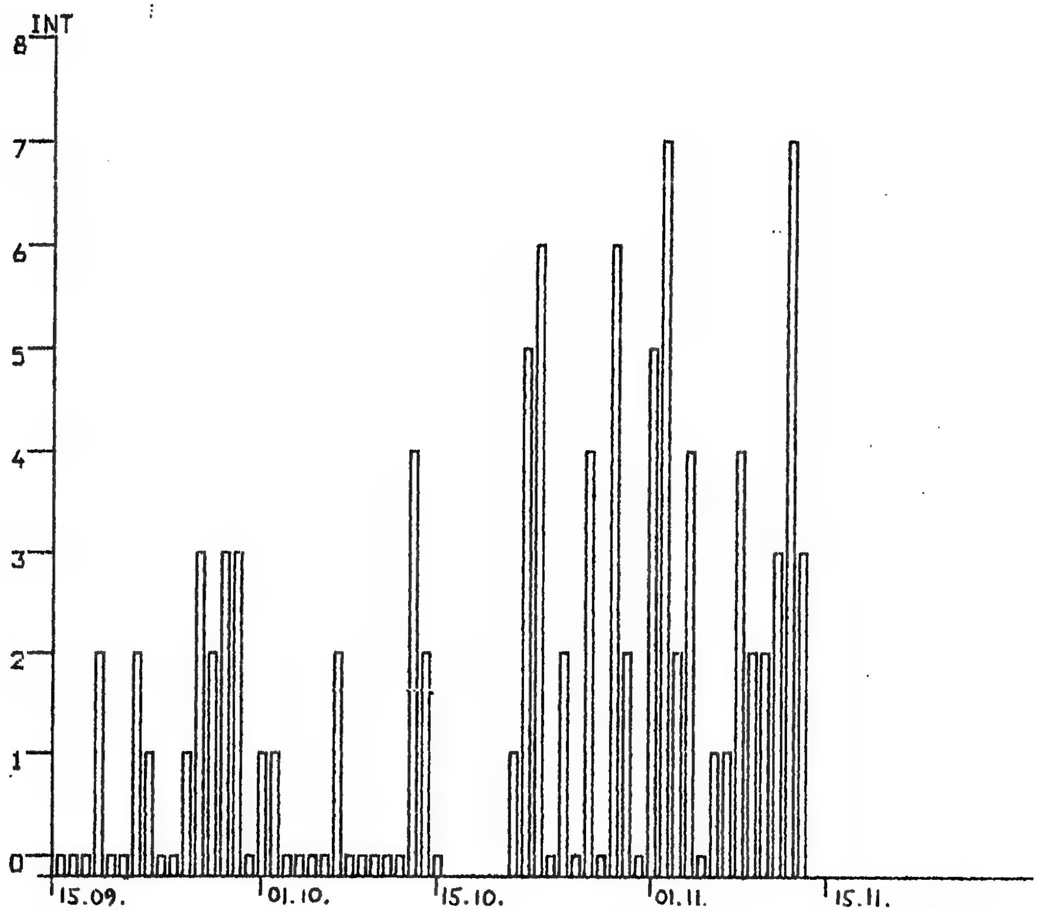


FIGURE 6 Survey of the German bird migration forecast and warning system

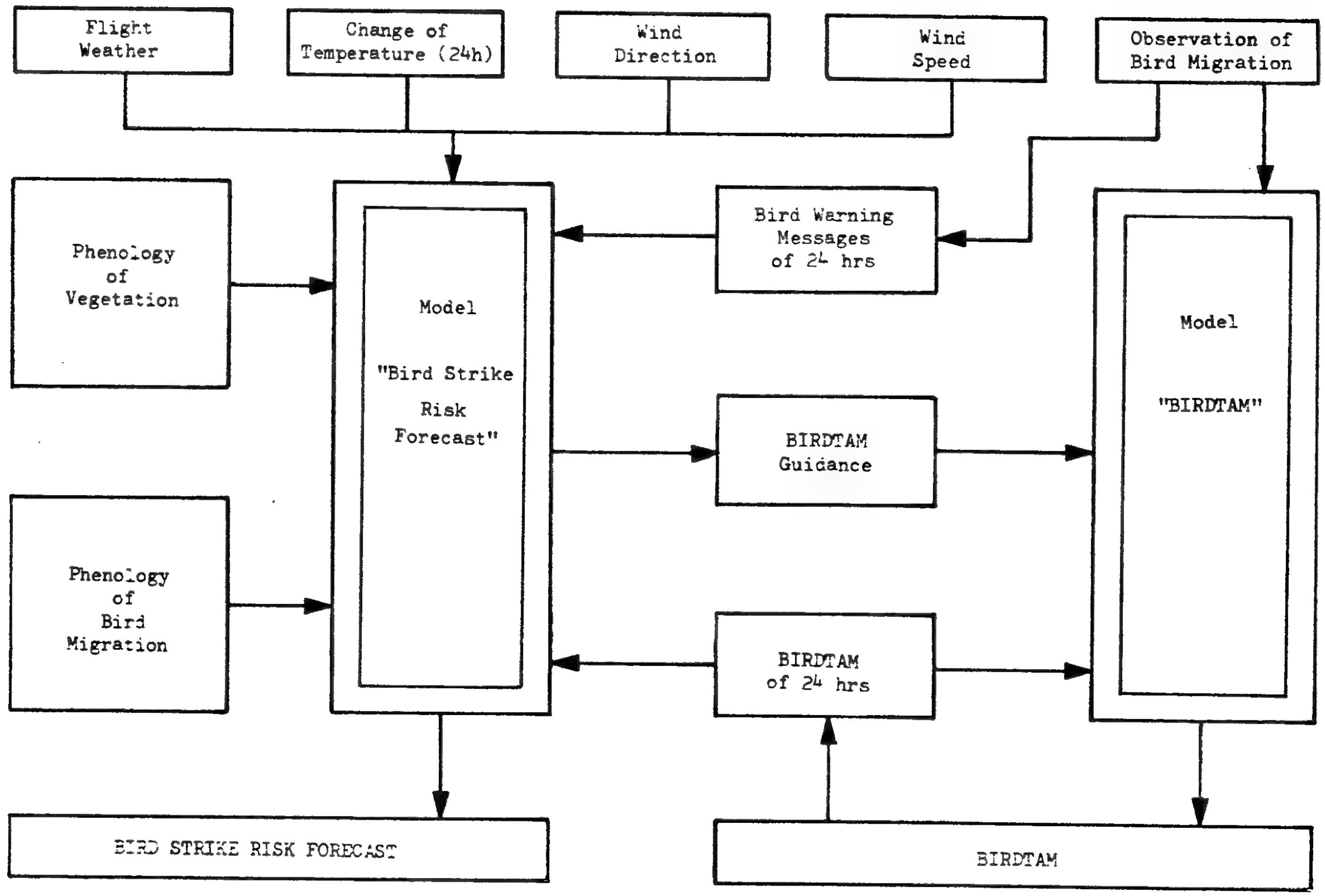
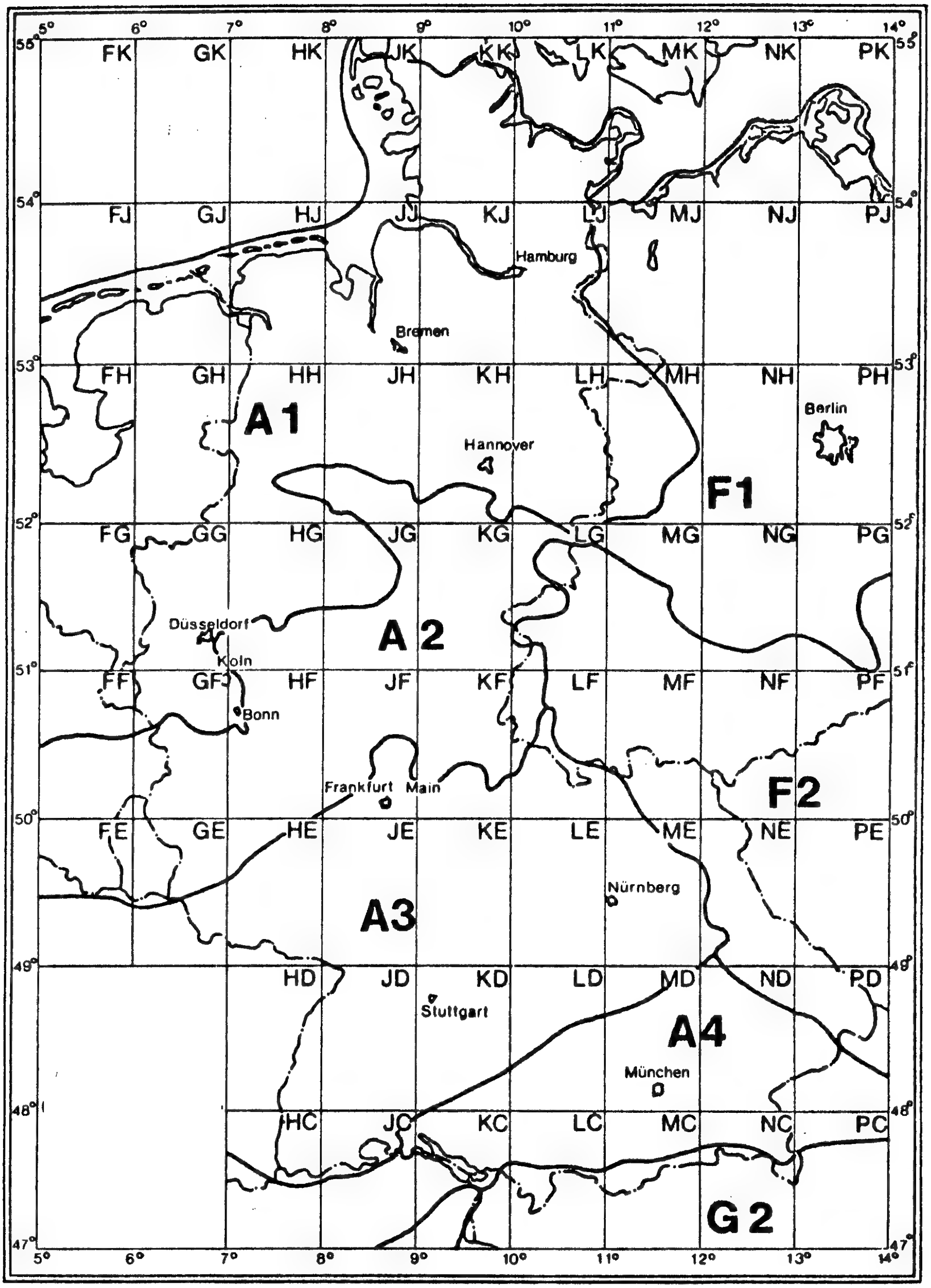


FIGURE 7 Reference areas of birdtam (GEOREF) and bird strike risk forecast (areas A1 - A4)



ADF616096

BSCE 18/WP 6
Copenhagen May 1986

FRIGHTENING DEVICES IN AIRFIELD BIRD CONTROL

Russell P. DeFusco

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Tyndall AFB, Florida 32403

Abstract

The United States Air Force Bird-Aircraft Strike Hazard (BASH) Team has developed a slide-tape presentation demonstrating safe and proper use of airfield bird frightening devices. While written guidance exists on use of these devices, personnel frequently use incorrect frightening techniques. This demonstration will be distributed Air Force-wide for the purpose of standardization and training in proper airfield bird control. The presentation will be available to other agencies through DAVA, Norton AFB, CA 92409.

Slide-tape presentation approximately 25 minutes. No attached paper.

AOF616049

BSCE 18/WP 7
Copenhagen May 1986

BIRD HAZARD WARNING USING NEXT GENERATION WEATHER RADAR

Captain Russell P. DeFusco, United States Air Force
Dr. Ronald P. Larkin, Illinois Natural History Survey
Dr. Douglas B. Quine, Illinois Natural History Survey

HQ Air Force Engineering and Services Center
Tyndall AFB, Florida 32403-6001

Abstract

United States Air Force Bird-Aircraft Strike Hazard (BASH) Team is sponsoring research to utilize an algorithm designed to detect birds on the nation-wide Next Generation Weather Radar (NEXRAD) system currently being developed. A phased approach to the task of algorithm development separates flying radar targets into several classes: waterfowl, passerines, blackbird roosts, gulls, raptors, bats, and insects. Data was collected for all classes and a draft algorithm was prepared for waterfowl in the first phase. A second phase is underway to test the waterfowl algorithm and to draft and compare a migratory passerine algorithm. Research has confirmed that the NEXRAD system can distinguish the different classes of targets and can distinguish birds from weather. Ultimately this system will provide real-time bird hazard warning information on a continent-wide scale.

ADF616048

BSCE 18/WP 8
Copenhagen May 1986

1984-85 USAF BIRDSTRIKE REPORT

Michael M. Thompson
Russell P. DeFusco
Timothy J. Will

HQ Air Force Engineering and Services Center
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Abstract

The United States Air Force Bird-Aircraft Strike Hazard (BASH) Team has maintained birdstrike records for the USAF since 1975. Although some data is available from as early as the 1960's, inconsistent reporting procedures and incomplete information limits its use. Not until 1982 have awareness programs and mandatory reporting procedures resulted in consistent birdstrike reporting throughout the Air Force. Finally, we are getting a more accurate picture of the overall impact birds are having on our aircraft. This paper presents 1984 and 1985 USAF birdstrike data and analyzes and compares data from 1983 (BSCE 17), 1984 and 1985.

ADF616049

BSCE 18/WP 9
Copenhagen May 1986

TOXIC PERCHES FOR CONTROL OF PEST BIRDS IN AIRCRAFT HANGARS

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Abstract

The United States Air Force Bird-Aircraft Strike Hazard (BASH) Team has taken a special interest in resolving problems with pest birds in aircraft hangars. A variety of pest bird removal methods has provided limited or unsatisfactory results, causing concern at several CONUS bases. The toxic perch method was evaluated in large hangars supporting as many as 20,000 Rock Doves, House Sparrows, and European Starlings. The perches contained a liquid solution of endrin or fenthion, which was absorbed through the birds' feet while perched. Results from six Air Force bases indicate the toxic perches successfully removed 95-100% of pest birds from inside the structures within 4-30 days without complications or secondary poisoning of non-target species.

INTRODUCTION

The United States Air Force's Bird-Aircraft Strike Hazard (BASH) Team has taken a special interest in resolving problems with pest birds in aircraft hangars. These structures are extremely alluring to birds, which seek the roof-supporting I-beams and bars for nesting sites and shelter. Aircraft hangars typically harbor thousands of pest birds in close proximity to the runway. The pest birds not only pose a significant BASH potential, but create costly maintenance problems. Bird nesting materials, feathers, and droppings fall onto aircraft and equipment causing damage to aircraft parts and corrosion of skin paint. Facility cleanup costs, personnel morale problems, and support equipment damage all further necessitate removal of pest birds from hangars.

Aircraft hangars are built with the intent of creating a sheltered environment in which to perform maintenance, conduct inspections, and otherwise operate on aircraft. Although some hangars have been converted to storage facilities, training centers, and even office space, all hangars were originally constructed to accommodate one or more aircraft with their high tails and wide wingspans. To avoid using support columns for the roofs of hangars, which would limit space and access, a system of metal trusses, reinforced by bricks, concrete and iron rods, serves to hold the roof in place. High bay doors, which roll on railroad tracks, provide the space necessary to bring aircraft into and out of the hangar.

The high, protected areas created by hangars provide excellent roosting habitat for three pest bird species: Rock Doves (domestic pigeon), (Columba livia), European Starling (Sturnus vulgaris), and House Sparrows (Passer domesticus). Even when doors are closed, birds are able to find access through broken windows, small holes, and ventilation ducts. Once inside, birds usually search for suitable nesting/roosting sites in the overhead structure.

A variety of pest bird control methods have provided limited or unsatisfactory results causing concern at many U.S. Air Force bases, while other methods have proved extremely successful. The BASH Team has monitored these methods and noted degrees of success for specific cases.

The purpose of this paper is to provide a better knowledge of structural pest bird problems and to summarize control methods which offered varied success on Air Force installations.

METHODS

Structural Design

Rarely are birds considered when designing any aircraft facility, but there are several alterations which could decrease pest bird problems. One new concept in hangar design suggests moving the support beams to the outside of the structure. This makes roost sites less available, and keeps any droppings away from people and planes. Some Air Force hangars have been fitted with a "false ceiling" just below the level of the superstructure. Although birds can still roost in the support beams, droppings and feathers fall onto the false ceiling and don't reach the floor. With some thought from planners, a variety of other design features could easily incorporate methods to reduce pest bird problems inside hangars.

Netting

Plastic netting can be used to exclude birds from the hangar superstructure. The BASH Team observed two hangars employing the netting method, and found it successful, though its use restrictive. The netting excluded birds from the

superstructure, but because of the design features of both hangars, birds had access to other inside areas such as above hangar doors, on wall and window ledges, and through vents in the roof. Although birds were fewer, the hangars were not bird-free; and while no birds were intentionally killed, many were caught inside the netting.

Plastic Strips/Netting over hangar doors

Vertical plastic strips and netting can be used to seal off hangar doors. Netting must be raised and lowered to allow aircraft to pass through the doors. Both these methods prevent some of the birds from entering, but do nothing about birds already in the hangar. Additionally, birds can still roost in the door bay or directly over the doors.

Sharp Projections

The chief problem with wire projections for bird control is the number of roosting sites which must be covered inside the hangar. Since the cost of such a plan is so prohibitive, the Air Force has never tried to bird-proof a hangar in this way. There are, however, many smaller areas where projections could be useful, such as perches outside hangar entry points, or along ledges on the outside of the hangar.

Rotating beacons/Shiny objects

Lights, reflectors, etc., can affect birds by initially distracting them and frightening them into hiding. Building managers have attested, however, to the brevity of their usefulness, as the birds quickly become familiar with the steady sweep of the light or movement of the reflector. Even strobes have shown no lasting results, since the birds sense no real threat.

Stuffed owls/Rubber snakes

Sometimes known as "scarecrows for buildings," these items have had very little or no effect on birds. The reason they are even included in this list is because so many pest managers and building supervisors have purchased them based only on the merchant's recommendation. They are placed on overhead beams and ledges only to have the birds stand on them or peck at them a few days after installation.

Ultrasonic Devices

Air Force policy bans the use of ultrasonics, since birds are incapable of perceiving ultrasonic frequencies. No high-frequency, sound-generating equipment has shown success in removing birds from Air Force structures.

Loud music/Other noises

Some hangar managers have reported success playing loud music or variable noise generators. The typical response is for birds to move as far as possible from the sound source, perhaps to the next bay area, but not out of the hangar. Problems result when workers become irritated by the noise, and when the birds realize there is no threat. Birds invariably return at night when the music is turned off.

Night harassment

If birds can be repeatedly disturbed at night, they will search for other areas to roost. Methods used to annoy birds have included high-pressure water to knock them off perches, and falcons which attack individual birds, scaring off the others. Night harassment is very labor-intensive, and often aircraft and equipment must be removed from the hangar before any action is taken. Very little is known on how long it takes to dislodge birds from a hangar roost, or how long they will stay away once removed. There is a great probability,

however, that they will simply move from one hangar to another if harassment is the only approach taken.

Hawks/Falcons

These hunting birds can be very effective in removing pest birds. The base currently using this technique reported that hangars were bird-free for two to three months before the hawk was brought back to clear pigeons. This procedure is labor-intensive, and requires specialized training and coordination to be effective.

Shooting

The BASH Team frequently recommends shooting hangar pest birds with pellet guns. Shooting has been particularly effective in smaller open structures. However, it is difficult to remove all the birds in a hangar since many only return at night, and others are very adept at hiding in support beams.

Trapping

Many bases have used trapping effectively, especially for pigeons. The best programs employ Australian Crow traps large enough for a man to stand in. These have one-way entrances for birds and provide perches and food/water for captives which serve as decoys.

Chemical Irritants

These usually come in the form of a gel or liquid, and create a chemical "hotfoot," or a tacky surface, making it uncomfortable to stand wherever the chemical is applied. Tanglefoot, Roost-no-More, and 4-the-Birds are products which have been used in Air Force hangars with limited success. Hangar personnel have reported that reapplication of chemicals was frequent because of dust and dirt accumulation. In hot conditions, some brands will melt and run down walls or drip to the floor. Although companies claim that their products last for over a year, this has not been proved by the Air Force. Also, hangars were never really free of birds because there were too many surfaces where the chemical could not be applied, leaving areas where birds could still roost. The number of beams and ledges in an aircraft hangar makes this method very difficult.

Avitrol

Avitrol has been effective in structures where birds can be confined or where a food source can be established. A variety of poisons are available for pest birds, but until recently, Avitrol was the only one used in connection with Air Force hangar problems. It is very important to ensure prebaiting is done properly to allow the entire population adequate time to adjust to the food source. Sometimes more than one population may be involved, and multiple feeding stations may be required.

Toxic Perches

The BASH Team examined toxic perch use at six bases for pest bird control. The toxic perch concept is not a new one, though this was its first use in aircraft hangars. Tube perches are filled with 9.4% endrin or 11% fenthion in an oil base. The perches act as a reservoir for the chemical solution which is fed from the interior of the perch through a wick to the top of the perch. When birds light on the perch the solution is absorbed through the feet. Perches are designed 30 inches in length and round or flat to accommodate various pest birds. The perches are then strategically placed inside the hangar after observing perching habits of the birds. The following observations are not conclusive, nor are they part of a scientific study.

Beale AFB, California. Seven hangars (20,000 ft^2) contained approximately 100 pigeons in each. A total of 318 endrin perches were installed in the 7 structures. Fifty-percent of the pigeons were reported to be eliminated within 3 days; 75%, 5 days; and 90%, 7 days. Six hundred birds were recovered at the site. No non-target species and no secondary poisonings were reported.

Vance AFB, Oklahoma. Six hangars (6,000-57,000 ft^2) contained approximately 600 starlings, sparrows, and pigeons. Fifteen to 125 endrin perches were installed per hangar. Fifty-percent of the birds were eliminated within 2 days; 75%, 3 days; 95%, 4 days; and 100%, 6 days. No non-target species and no secondary poisonings were reported.

Dyess AFB, Texas. One hangar (80,000 ft^2) contained starlings, sparrows, and pigeons. Two hundred thirty-three fenthion perches were installed. Fifty-percent of the birds were eliminated within 15 days; 90%, 20 days; and 95%, 30 days. All starlings and pigeons were eliminated. No non-target species and no secondary poisonings were reported.

Dobbins AFB, Georgia. One hangar (30,000 ft^2) contained approximately 50 starlings and 50 sparrows. One hundred fifty endrin perches were installed. Ninety-five percent of birds were eliminated within 10 days and 100% within 30 days. No non-target species and no secondary poisonings were reported.

Bergstrom AFB, Texas. One hangar (62,500 ft^2) contained approximately 1000 pigeons, starlings, and sparrows. Forty endrin perches were installed. Fifty-percent of the birds were eliminated with 10 days; 75%, 30 days; and 90%, 45 days. Sixty additional fenthion perches were added to remove entire population. No non-target species and no secondary poisonings were reported.

Altus AFB, Oklahoma. One hangar ($160,000^2$) contained 20-30,000 starlings and 200 pigeons. Three hundred fifty fenthion starling perches were installed. Ninety-nine percent of the starlings and 25% of the pigeons were reduced within 30 days. Seventy pigeon perches were added to eliminate the remainder of the pest population. No non-target species and no secondary poisonings were reported.

These case studies represent positive results with toxic perch use within aircraft hangars. Endrin perches successfully reduced 95-100% of pest birds from inside structures within 4 to 10 days while fenthion perches reduced 95% within 30 days (Figure 1). None of these case studies resulted in reported secondary poisoning; however, a potential does exist. Since endrin and fenthion produce the same results within a reasonable period of time, the Air Force position will be to use fenthion as the active toxicant for subsequent studies until controlled tests showing secondary poisoning effects are completed.

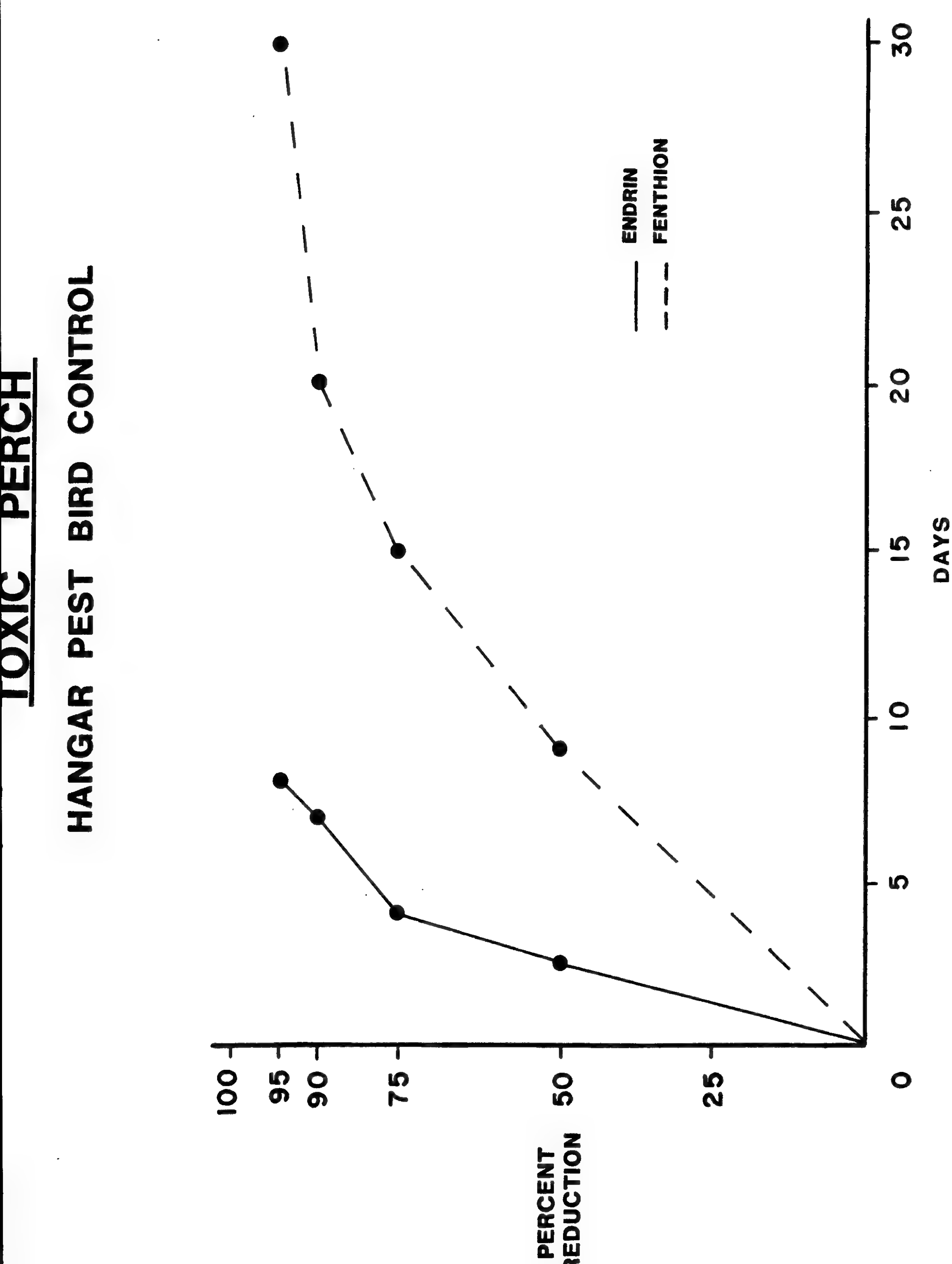
Denver Wildlife Research Center conducted a preliminary test for the potential secondary hazards of fenthion-killed starlings and pigeons to avian predators/scavengers. Two cold-stressed Black-billed Magpies (*Pica pica*) and two heat-stressed magpies which were fed poisoned birds died within 4 days. Two non-temperature stressed magpies were unaffected even though a large amount of bait was consumed.

These results indicate the concentration of fenthion used in perches is near the limit for causing secondary toxicity in avian scavengers. Further testing is required to determine appropriate chemical and concentration to minimize secondary toxicity to other animals.

CONCLUSION

The BASH Team will continue to evaluate methods of dealing with pest birds in hangars. The toxic perch method has provided the best results for our worst-case situations; however, several issues need to be resolved concerning secondary poisoning effects. Total reliance on one technique is still impractical, and the BASH Team will continue to maintain a diversified approach to meet the requirements of all Air Force hangars. A reduction in hangar pest birds will reduce BASH at our airfields and will ensure the skies are safer for our aviators.

FIGURE 1



TOXIC PERCH
HANGAR PEST BIRD CONTROL
PERCENT REDUCTION
100
95
90
75
50
25
0
5
10
15
20
25
30
DAYS
ENDRIN
FENTHION

ADP616050

BSCE 18/WP 10

REDUCTION OF WILDLIFE HAZARDS TO AIRCRAFT

VEF Solman, Wm. J. Thurlow
Environmental Control Consultants (1981) Ltd
P.O. Box 2425, Stn "D"
Ottawa, Canada K1P 5W5

Reduction of wildlife hazards to aircraft depends more on the state of mind of the people involved and their hard work than on all the technology we have developed. The state of mind we need involves a great deal of determination to work on the problem each and every time it occurs and to use all of the knowledge, ideas, and technology we have, to control creatures which have more time than we do to learn how to take advantage of their environment and make a living. In doing that, these creatures cause us problems in ways that continually amaze us.

You need to keep one thing in your mind, always, in regard to wildlife problems. That is never to become complacent and assume that there is no problem or that you have solved the problem. I have seen too much of that where you do all the obvious things you have read about in all the published papers, you have attended the lectures, and you think you know how to do it. You get out there, you do all the right things on the airfield and then something happens that neither you nor anybody else had experienced or thought of before. A few examples: At Stephenville, Newfoundland, on the 5th of September, 1980, an Eastern Provincial Airlines B737 hit gulls on take-off, had a JT8D engine take fire and disintegrate for a replacement cost of $1.2 million. There had been no previous reported strikes there though gulls had been seen with increasing frequency during a period before the strike. Unfortunately no one was thinking much about bird hazards there because they had had no previous problems and nobody was doing anything there to discourage the gulls. Murphy's law worked and that airplane got hit. If the engine fire had not gone out when they fired the second fire bottle, there might have been casualties. They were lucky; they got away with it. On January 19, 1979, a Wien Alaska B737 struck a covey of ptarmigan just after landing at the airport at Mcgrath, Alaska. Both engines ingested birds; one was heavily damaged. Ptarmigan

with their white winter plumage don't show up very well against a snow background. The airline sued the State, which operated the airport, for $\$1\frac{1}{4}$ million and the State had to pay. State officials called me and asked what they should have been doing about all this? I looked at their records and it turned out that ptarmigan, which move around the country in the wintertime, had been seen a few times around the airport but none had been struck by an aircraft at that airport so no one paid any attention. There was no bird control program at the airport.

At Dunsfold in Surrey, England, at a company-operated airfield there was a well-organized bird management plan in place with staff trained to deal with bird hazards when requested to do so by the air traffic controller. All personnel on the airfield were supposed to report observations of birds on the airfield to the controller. On November 20, 1975, an HS 125 took off, after checking with control that no bird reports had been received, ran into a flock of lapwings, lost power on both engines just after rotation, landed back on the runway, ran off the end, through three hedges, across a road where it struck and demolished a station wagon and killed 6 persons, stopped in flames and burned out. Crew and passengers (9) escaped. The investigation showed that some airport people had seen birds on the airfield prior to the take-off but had assumed that "someone else" would have reported them to the controller. All the training and equipment was wasted and 6 lives lost because the good bird control system was not activated.

I mention these historic examples because they make the point better than anything else I can say. You have to be thinking about these things all the time. You have to know the kinds of things that might happen and always realize that birds and mammals do things that can cause problems. That must be in your mind all the

time. You have to have everybody on the airfield helping you. If you don't know that birds or mammals are there you may not take the kind of action that will prevent accidents.

Some of our recent published work has shown the differential vulnerability of turbine engines of different sizes and different locations on the aircraft. That should remind you that, if for example the Canadian Armed Forces change from B707-320 aerial tankers to DC10 tankers as the U.S.A.F. has done recently, underwing engine strikes can be expected to go up from 0.32 per 10,000 engine movements to 0.47 while the tail engine on the DC10 will have a strike rate of only 0.16 per 10,000 engine movements.

We have known for quite a while that some underwing engines have more than four times as many bird ingestions as rear-mounted engines of the same size and that larger, quieter engines have higher strike rates than smaller noisier engines. So what do the designers do? The biggest-selling modern transport aircraft are big, quiet twins with underwing engines, exemplified by the Airbus 300 and the Boeing 767. This means that bird hazard reduction is increasing in importance daily if we want to avoid serious incidents.

I have talked about transport aircraft. Executive aircraft such as learjets, falcons and challengers have the good feature of rear-mounted engines but also have all the problems related to small engines which can be damaged by relatively smaller birds. These aircraft have the added problem of flying, some of the time, from smaller airports with less awareness of bird problems and less staff to deal with those problems.

High performance military aircraft share with small transports the small engine problem compounded by the very high performance extracted from those engines in military service.

Many of our housekeeping practices on airfields can work to the birds' advantage if we are not very careful. When we use urea for runway ice control we inadvertently fertilize the soil at the runway edges. On prairie airports the grass is noticeably greener along the runway edges. The ground squirrels concentrate there as do the hawks that feed on them. The increased likelihood of bird strikes can only be controlled by the control of ground squirrel numbers in those runway-edge areas or by the control of ice with something that is not a fertilizer.

We cut down trees and shrubs on airports to remove cover used by birds. As the cover grows back it may be used by birds other than those we originally got rid of and so the problem changes but there is still a bird problem.

Birds change their distributions, numbers, and even habits over time. When the municipal garbage dumps at North Bay and Trenton were situated near the airport years ago, gulls were known to feed on dumps but gull numbers near the airport were small and did not pose much of an immediate problem. Over the last ten years the populations of Ring-billed gulls in Ontario have increased by about 10% per year. Some of the biggest gull colonies known are now in Ontario. Without very expensive gull control programs at both airfields, on a conitnuing basis, the strike rates at both Trenton and North Bay would be unacceptably high.

Sometimes things off the airports, other than garbage dumps can cause airport bird problems. Franklin's gulls live over much of the prairies eating insects in crop fields. At an airfield like Regina, which has grain fields on three sides, when the harvest starts the noise of swathers and combines in the fields causes thousands of gulls to leave the fields and move to where there is less disturbance- onto the Regina Airport. After a couple of years of experiencing the

had just collided with a flock of cowbirds which rose from a dump near the runway. He called the control tower and said, "We have hit some birds; we are not going to make it." and then crashed.

That crash, which destroyed the aircraft and killed its seven occupants, started a legal process which passed through the local court, the state high court, the U.S. Supreme court; and involved county officials, the FAA, the insurance company which carried the liability insurance on the airport, and almost everybody in sight. As Doc said, "Everyone was sued: the county was sued, the county commissioners were sued as a body and as individuals, the airport manager was sued." The settlement, after 9½ years it took, involved payment of between 400 and 500 thousand dollars for each death, as well as payment for the destroyed aircraft and for repairs to damage to buildings and other installations. The payments were shared by the FAA and by the insurance company. In the Dunsfold crash the company which owned the airfield and the aircraft paid for the losses in an out-of-court settlement.

I mention the matter of liability because it is always there in the background as a further incentive to do a good job of controlling wildlife hazards to aircraft. If you fly yourself you already have a more personal reason for excellence. "The life you save may be your own." I can't think of a better incentive for good work.

We have said a lot about bird strikes on and near aiports. While they are important we must not lose sight of those that occur away from airports. Another area of increasing concern involves mammal strikes and other actions of mammals which also cause danger for aircraft.

Birds aloft, away from airports, are a threat to all aircraft.

sudden arrival of large numbers of gulls in late August, the Airport authorities now get ready in advance each summer by laying in supplies of shell crackers and other scarers and by arranging for extra manpower and vehicles for much increased anti-bird patrols for the week or so that the problem exists.

Sometimes a nearby industrial area can cause problems, not just through waste food on the ground in drive-in theatres and in supermarket garbage, but also through architecture. Industrial areas on flight ways have height restrictions and adjacent buildings are often flat-roofed with parapets around the roof edges. These become problems when drains plug up in wet weather and water pools on the roofs. A few hundred gulls bathing and loafing on a water-filled flat roof can panic and fly up in front of approaching aircraft just as they would off a wet area of ground near the end of a runway. Unfortunately, while they are seen by approaching pilots, all too often they can't be seen from the ground or the control tower because they are behind the roof-edge parapet. We had that problem at Toronto International airport years ago. It was solved through the cooperation of the building operators when airport staff visited them, pointed out the problem and their possible liability in case of an accident. The whole matter of liability is becoming a real issue in some countries involving long drawn-out court battles, one of which lasted for nine years after the crash of an executive jet at Atlanta, Georgia, in 1973, involving seven deaths. Let me report briefly on a paper given by the airport manager, "Doc" Manget, at a conference on airport wildlife control at Detroit in August, 1983.

"Doc" Manget began his paper by referring to three sets of famous last words. Madame de Pompadour, after receiving the last rites from a priest who began to leave her room said, "Wait for me, I will go with you," and died. Stonewall Jackson, mortally wounded, lay on the bank of a river, said, "Let us cross over the river and rest in the shade of the trees." He then died. Doc Manget said the saddest last words in his view, were those of the pilot of the Learjet 24 who

Because of their high-speed, low altitude missions are particularly serious for military training and operational flying; much more so than transport aircraft which spend less time in low level flight. and fly more slowly thereby greatly reducing the seriousness of the damage. Cruising above 30,000 ft. is relatively safe because few birds get that high. The greatest in-flight hazard occurs during long distance bird migration when birds may fly at altitudes of up to 15,000 ft. (occasionally higher) to secure the favourable wind speeds and directions needed to accomplish long flights on limited fuel supplies (mostly stored fat). Birds show up well on most radars and their migrations can be forecast in relation to weather forecasts so since the late 1960's it has been possible to schedule flying training at military bases like Cold Lake, Alberta to avoid the heavy migration traffic particularly of large birds.

It is only in the last few years that we have begun to collect information on mammal problems. The number of mammals hit is smaller than the number of bird strikes but the hazard must be considered and dealt with. Deer strikes are perhaps most common and can cause a great deal of damage especially on smaller aircraft. At least one 104 has been written off and the pilot killed by a rabbit strike.

Just as important as strikes is the flooding caused by beavers which can knock out lighting and communication wiring and provide habitat for water-loving birds where it is not wanted. Wolves and Coyotes break runway lights at some northern airports and enjoy chewing on runway light wiring. At one northern airfield one quarter of the maintenance staff is employed for the continuous replacement of damaged lights and wiring. Not only is this an item of expense and a problem for a limited staff but a lighting and/or communication failure at a critical phase of landing could cause a serious hazard.

Mammals may chew external plastic and rubber fittings on parked aircraft as well as entering the aircraft to damage interior fittings. The light-hearted story in "Flight Command #3" * of 1985 should remind us of the serious consequences of mammal damage to aircraft and ground components which could lead to their failure. At Sea Tac International Airport near the Northwest corner of the U.S., liquor supplies are piped from the main terminal bar to those in the satellites through plastic tubes. When the bar records in the satellites did not match withdrawals from stock in the main terminal, the tubes, which run in tunnels with electric power and communication cables, were examined. Chewing rats had caused leaks in the tubing and some damage to insulation on electrical cables. In at least one instance in an airport outside North America rats or other rodents had damaged power cables for radar installations thereby shutting down the system .

I mention a few mammal problems to encourage you to be on the alert for mammals and mammal damage - just as you are for birds and their actions. As we work harder we will find more ways that mammals are causing trouble just like birds. Relatively recently the first bird nest, made of wire from power sweeper brushes was found in an aircraft. That means bird nests can now cause short circuits and fires as well as mechanically plug duct and joints. We don't know just what new problems birds and mammals will cause in the future. A senior member of the original associate committee on bird hazards to Aircraft - which pioneered many bird damage control ideas during its life from 1962 to 1976, said, "Birds are almost always nearby everywhere." He was right about birds and the same thing probably applies to mammals. We must be very alert to keep up with them, let alone get ahead of them. Constant vigilance is needed to maintain our present level of safety. We must try very hard to improve it. Remember-the life you save may be your own-Keep at it.

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*published by D.N.D.

ADF616051

Last activity paper of the Working Group (October 1984, Rome)

Bird Movement Working Group.

ACTIVITIES OF THE WORKING GROUP.

1. Title : Bird movement Working Group.

2. Terms of Reference:

Study of bird concentrations and movements; drawing up of special bird hazard maps for informal and planning purposes.

3. Progress report

a) Copies of the standardized European birdstrike risk map (scale 1 : 2.000.000) had been distributed to the countries. There is no further information f.i. coming from radar observation which could require a new or better map.

b) Birdstrike risk maps published in the national AIP are still valid.

c) Chairman of WG prepares a collection of maps about wildlife reserves, bird sanctuaries and moist areas in Germany (encl.) as a basis for an informal map collection especially for general aviation, sports and sail flying as well as for military aviation.

d) Data have been collected about bird concentration areas in the vicinity of international airports as a basis for a special pilot-handbook which can be used also by ATC-personal observing birds in the vicinity of airports.

4. Future program

a) Collection of data about wildlife reserves, sanctuaries and moist areas of international importance for all European countries.

b) Collection of data about bird concentration areas in the vicinity of international airports.

5. Recommendations

a) Most of the existing bird movement and bird concentration maps are dating from 1974 - 1978. A revision of the maps seems to be necessary. New data about bird concentrations and bird migrations should be collected by each country and sent to the chairman of the bird movement W.G.

b) Collection of data about wildlife reserves, sanctuaries and moist areas in all countries and drawing up of informal maps-. Summaries should be sent to the chairman of W.G.

c) Collection of data about bird concentration areas in the vicinity of all international airports. Surveys should be sent to the chairman of W.G.

d) Countries are requested to name persons/members for active cooperation within the W.G.

Agenda for Meeting Bird Movement Working Group

27th May 1986, 14.30.

1. Naming of members for the Working Group.
2. Election of a Vice-Chairman.
3. Progress report, given by the chairman.
4. Progress reports of the countries (delegates).
5. Progress with BOSS (report Belgium).
6. Further reports (delegates).
7. Future work of the WG, investigation program.
8. Recommendation.
9. Next meeting of the Working Group.

BSCE 18/WP 12

BELGIAN AIR FORCE

METEOROLOGICAL WING

STRATEGIES FOR THE IDENTIFICATION OF BIRD REMAINS FROM BIRDSTRIKES

SURVEY AND ADVANCED APPROACH BY BIOCHEMICAL ANALYSIS OF TISSUES

IN COLLABORATION
BY

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J.F. BOOMANS   SENIOR METEOROLOGIST, BELGIAN AIR FORCE
P. DE RAEVE   DR. VETERINARY – E. HOET DR. VETERINARY
B. VERACHTERT   LIC. BIOLOGY

1. Introduction

In 1965 the Belgian Air Force recorded 100 birdstrikes (BS), among these 44 with damage.

Actions to avoid or diminish birdstrikes are not only based on aerodrome measures and birdtam informations but also on information about the bird species involved, their behaviour and their way of living. This kind of information may be useful, e.g. to render airfields and their surrounding less attractive to some bird species.

Different bird species may respond in a different way to the same dispersal methods. It is therefore important to be able to identify them up to the species level in order to take the exact preventive measures.

Since several years, a group of biologists attached to the Meteorological Wing of the Belgian Air Force and a research laboratory at the University of LEUVEN collaborate at the same question within the frame of B.S.C.B.. This collaboration is of interest for both parties since a lot of scientific information concerning the flying habits of birds can be obtained from these birdstrikes.

This paper deals with some recent developments in the identification of bird species by means of biochemical techniques.

2. Species identification

2.1. Bird strike report

BS of the Belgian Air Force are reported by the pilot and (or) by the maintenance service personel. A special form (ICAO based) is filled out and sent to the Zoological Institute of the K.U.L. together with the bird remains in order to get the data necessary for an exact identification of the bird. In this way, Air Force and scientists get the maximum out of the available data.

2.2. Feather examination

2.2.1. Macroscopic :

Direct examination of the size, shape, colour and pattern of the feathers is the most at hand method to identify the bird : this is carried out at the Zoological Institute (K.U.L.). The weight of the remains is only a supplementary value since when large parts of the bird are recovered, the plumage is mostly amply sufficient for a correct identification of the bird. This method is simple, cheap and may lead to rapid results. In 1984 and 1985 approximately 50 % of the remains could be identified up to the species level.

2.2.2. Microscopic :

This method is based on the work of T.C. Brom of the University of Amsterdam. The feathers are mounted under a coverslip and examined under the microscope. The downy parts at the base of the shaft of the feathers particularly possess a microscopic structure characteristic for each family and even species of bird. These plumes are very suitable for microscopic examination because most of the times they can be found sticking in blood on the aircraft. It is very difficult to identify them macroscopically (14th meeting B.S.C.E. THE HAGUE).
The results of previous investigations show that several samples of bird remains could be satisfactorily identified, even when burned and carbonized by the engines (Veilig Vliegen Jan 80).

This technique was a great progress in the positive identification of birds so that the number of unknowns decreased.
A study about the effect of succesful identifications on BS statistics of the RNAF by L.S. Buurman and T.C. Brom stipulates that the identified samples increased with the factor 10 from 5 % in 1974 to 52 % in 1978.
Attention was also drawn on the fact that the relative importance of a certain bird species is dependent on the identification ratio and the ratio of BS with damage. Birds that are easy to recognize, such as white and large ones, also influence the statistics in their favour. The same phenomenon occurs for BS with sufficiently intact remains, e.g. during take off or landing. Otherwise, the statistics may underestimate some species and overestimate another. This might lead to the wrong conclusions as to the preventive measures to be taken and as to an optimal use of the available means.

2.3. An advanced approach : Biochemical analysis of tissues

Although the feather remains allow identification in a great number of cases, still to much remain unsolved, in casu those where no suitable feathers are available. However, most of the times, some blood or tissue can be recuperated.
Several biochemical techniques have been suggested to analyse these samples. The biological molecules of importance are proteins. Each species has its own typical set of proteins.
Principally, these techniques are all based on the same idea : the main components in the tissues are separated and visualized. This always occurs in a specific pattern for a specific species : in this way one can get as it were a kind of fingerprint of the species involved. The obtained pattern is compared to those stored in a kind of library that contains all possible patterns of birds to be expected in the area.
The most important techniques are shortly discussed with their main advantages and drawbacks.

2.3.1. Thin layer or paperchromatography

A small sample of tissue or blood is dissolved in a "running buffer" (mobile phase). A small spot of this solution is positioned on a special kind of filtration paper (stationary phase)(fig 1A). When the paper is brought into contact with the running buffer, the solution is sucked up (fig 1B). In this way, the proteins are transported and separated, depending on their molecular weight and other chemical properties. This results in a typical band pattern that can be stained and which serves as a kind of fingerprint for the proteins involved.

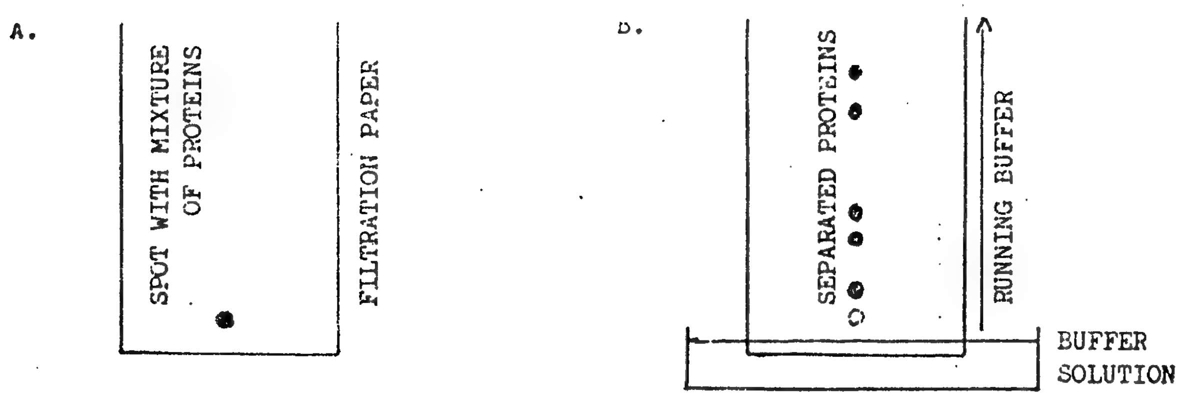

Fig 1 : chromatographical separation of a mixture of proteins.

Theoretically, complete separation of the complex protein mixture can be achieved. However, in practice, the method has not enough resolution to be able to separate all the different bird species.

2.3.2. Gas chromatography

The molecules are separated on the same principle as for paperchromatography but the mobile phase is provided by a gas (N_2). The sensitivity is determined by the lenght of the column through which the gas is chased. A longer column takes more time but the resolution becomes higher.

This technique is being used to determine the sort of flesh within the food industry with the aid of the fatty acid content of the samples. In this way, it's very easy to discriminate between cow and pig meat, whatever the presentation of it.

However, it takes a lot of skill to perform such an experiment, the apparatus is complicated and expensive and it would require

an awful lot of time to set up the protocols for all the different bird species. So, although the technique is very sensitive, it is only in some very specialised domains that its application becomes paying. More important still is the question if this method is sensitive enough to identify the birds up to the species level.

2.3.3. Electrophoresis

The resolution can be enhanced by applying the electrophoresis technique. The principle remains the same as for chromatography but the separation is mediated by the application of an electric field along the lenghth of the stationary phase.
Indeed, proteins are electrically charged in a typical way. These charges will enable the proteins to migrate under influence of an electric field. The velocity of migration is dependent on the molecular weight and on the netto electric charge of the protein. Proteins with the same charge, but a smaller molecular weight will move faster (sieving effect). On the other hand, proteins with the same molecular weight but a different netto charge will be separated because of their electrical behaviour.
Fig 2 illustrates some typical band patterns obtained with this technique on flesh samples of a few mammals. Even the untrained eye can discriminate between the different patterns.

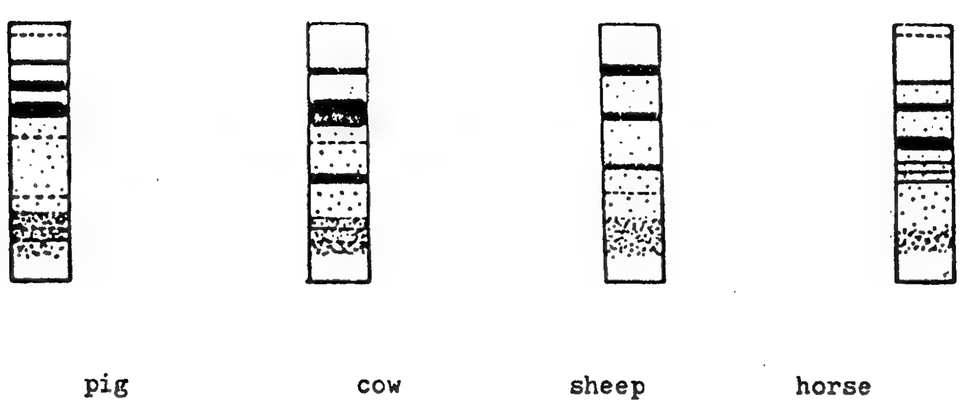

Fig 2 : electrophoretic pattern of a few mammals.

2.3.4. SDS electrophoresis

The electrophoresis technique can be further refined by a pretreatment of the protein solution with sodiumdodecylsulfate (SDS), an anionic detergent. SDS denaturates proteins by destroying their molecular structure into smaller pieces : the polypeptides. In this way, it is also possible to solubilise most of the heat denaturated proteins.

By coocking the sample on the beforehand at 100°C, the obtained polypeptide pattern is nearly independent of the pretreatment of the flesh remains.

Among other things, the technique is currently being used to demonstrate foreign proteins in heated meat (fig 3). It is possible to detect 0,1 % casein and 0,25 % soy.

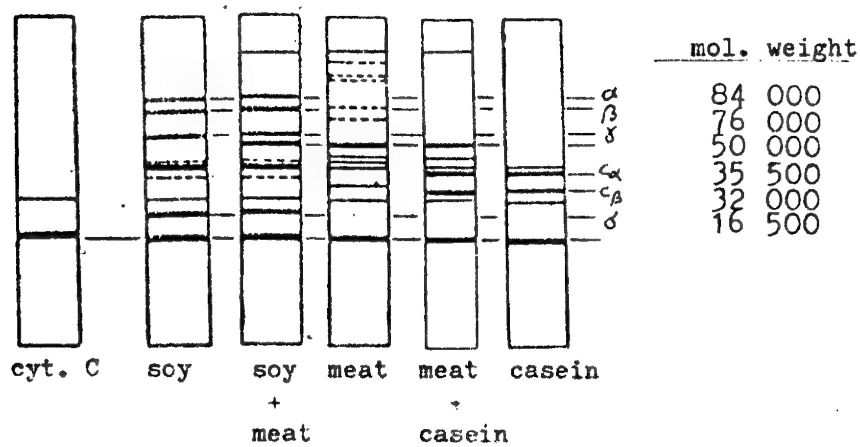

Fig 3 : SDS electrophoresis

The technique has the main advantage that it is possible to work with denaturated proteins and that the obtained band pattern has a high resolution and specificity.

2.3.5. Isoelectric focusing (IF)

By this technique the separation of the proteins is mediated through an electrically induced linear pH gradient.
At the R.U.G. Abrams et al (1983) tested AGIF (agarose gel isoelectric focusing) as a method to identify fish species.
A total of 53 species was examined. All 53 species showed a specific pattern in a highly reproducible way. Figure 4 illustrates the obtained results.

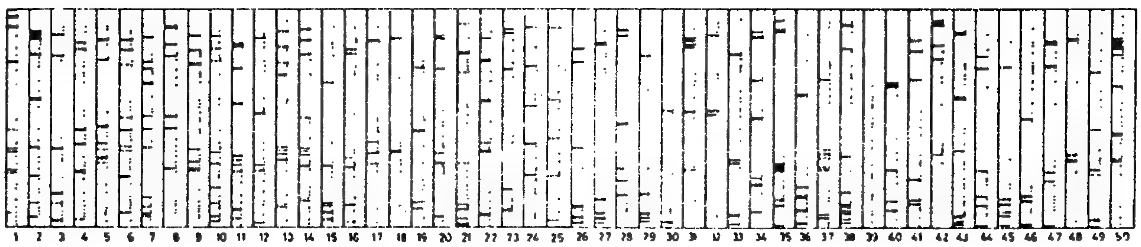

Fig 4 : Schematic patterns of fifty fish species.
(from Abrams et al (1983))

Also the effects of deepfreezing and storage at room temperature of the sample can be investigated.
IF patterns from fish extracts of the same species generally show a slight variation. Some faint bands may be slightly more pronounced or may even disappear completely.
The foregoing results illustrate that IF is a possible approach to the identification of bird species.
Still, there remain some problems : the proteins may not be denaturated, i.e. they are not to be exposed to temperatures higher than 50°C. Also, at this moment, the technique is slightly more complicated and more expensive than SDS electrophoresis.

2.4. Immunological investigation methods

The techniques currently developed are very sensitive, specific and can be applied with heat denaturated proteins. Usually, they are based on an antigen - antibody reaction.
These methods have the drawback that an antiserum against each species is required. The development and production of these antisera is very expensive and time consuming. To identify an unknown sample, each antiserum has to be tried out untill one gets a positive reaction. This is a very cumbersome way but perhaps the one to use in the future.

3. Conclusion

As a general conclusion, we may state that the best current biochemical analysis of BS remains could be provided by some electrophoresis technique. Introductory experiments will have to be performed to determine which one of these is the most suitable. During spring 1986 testings of the IEF-technique have been done at the laboratory of neurophysiology (K.U.L.) and already some preliminary positive results have been obtained.

A second phase should consist of the set up of a library with the patterns for all the bird species of a given area. This library should also provide the reference material to compare the samples.

When the system can be applied in practice, the percentage of exact identified BS samples will probably increase considerably.

If a 100 % identification should be requested, application of immunological methods should be considered.

ADDITIONAL BIBLIOGRAPHY

Brom, T.C. (1980)
Microscopic identification of feather-remains after collisions between birds and aircraft. (PhD thesis)

Abrams, R., Verbeke, R. and Van Hoof, J. (1983)
Fish species identification by isoelectric focusing.
(Fleischwitsch.63(9), 1459 - 1462)

Sibley, C.G. and Ahlquist, J.E. (1986)
Reconstructing bird phylogeny by comparing DNA's.
(Scientific American, 1986, 254, 68 - 76)

Rimpilainen, M.A. and Righetti, P.G. (1985)
Membrane protein analysis by isoelectric focusing in immobilised pH gradients.
(Electrophoresis 6,419 - 422)

ADF616053

WP/13

BIRD STRIKE COMMITTEE EUROPE
Study group "Communications"
Copenhagen 26th to 30th of may 1986

Communications TO and FROM the Pilot

by Captain D. RENOUX Air Inter France

"Communication" is the exchange of informations.
Concerning bird hazard in aviation, these informations can be written on paper or... radio waves. In both cases, pilots send or recieve them.

I. INFORMATIONS WRITTEN ON PAPER FROM THE PILOT.

They are mainly plane versus bird collision reports. This form should be filled after each collision. Alas, despite an inprouvement during the last few years, in relation with a pilot's greater concern, all the collisions with birds are not yet reported.

This concern should be enhanced in pilots training schools by lessons dealing with bird hazard in aviation, in Companies by lectures while annual refreshing courses and everywhere by papers about what is going on the subject, issued by State Aviation Departments.

The collision reports filled by pilots enable Official Services to conduct statistic studies leading to better knowledge of the risk, then to the settlement of devices to fight the risk, and finally to appreciate the effectiveness of these devices.

Thus, we see the importance of better reports. Airport Authorities cannot set up anti-bird equipment if they are not aware of most actual collisions.

But, would 100% of collisions be reported, the printed form only deals with actual collisions and neither with dangerous gathering of birds without accident, nor with avoided collisions by luck, chance, crew or bird manoeuvre.

I think we should report these non-collisions for a better knowledge of the risk. To speak like insurance brokers, to day we do not work on risks but on sinisters, which are bad consequences of risks.

II. INFORMATIONS WRITTEN ON PAPER TOWARDS THE PILOT.

1st/. Permanent circulation.

Studies permitted to draw charts showing permanent circulation of birds between feedinng areas and resting areas in the vicinity of many airports. These charts are included in A.I.P. (Air Information to Pilots). This enables the crew to manage their flights so as not to interfere with birds routes or, if impossible, to vacate them as soon as possible.

2nd/. Seasonal migrations.

Studies permitted to forecast seasonal migrations and to draw charts. Crew are informed by special notams called "Bird-Tam" precising dates, altitudes, axis and bird species. Same use than above, but as migrations are long haul flights not limited within the vicinity of airports, these informations are useful for the choice of cruising levels.

III. INFORMATIONS RADIO-TRANSMITTED BY PILOT.

After an actual collision with birds, pilots inform A.T.C. controllers, for them to make sure that birds corpses are removed from taxiways and runways; and then to record the incident. This is complementary to paper report first evoked here.

Besides, pilots inform A.T.C. contollers when they meet birds without collision, for them to warn following landing planes and aircraft attempting to take-off soon as well. This information, precious to avoid collisions though it be, is lost on the long term and now useless to make way in bird hazard fighting.

It is the reason why, I repeat, State Aviation Departments should act in order that non-collisions will be paper reported just like actual collisions.

Surely, of course, it is not prohibited to do so; but crew members are fond of papers and if some of us neglect to report actual collisions when the plane is not damaged, most, not to say all, will not report non-collisions if they are not officially urged to do it.

IV. INFORMATIONS RADIO-TRANMITTED TOWARDS THE PILOT.

Airport A.T.C. controllers used to warn crew when birds gathered near the landing axis, on the runway or nearby. Often, birds were signalled by prior crew. This is always true, but with the increase of the number of collisions -associated to the increase of the number of jet planes fitted with wide air intaked engines- airmen feel more concerned by bird hazard, and warnings are now more frequent.

More and more airports are now fitted out with ATIS (Air Terminal Information System). Crew listen to ATIS before or/and while descending. In any case, via ATIS, they get bird warnings long before landing. This enables them to anticipate their behaviour and take preventive measures like switching on the landing lights, perhaps the radar though its effectiveness is not prouved, reducing speed, delaying descent along intermadiate approach; whereas via A.T.C. controllers, the crew get bird warnings only when in final approach.

But ATIS should be regarded as a pre-information bacause it is not permanently updated. ATIS indicates a potential risk. Fortunately, birds wandering around an airfield are not permanently on the landing axis nor the runway. This ATIS pre-information ought to be completed by the A.T.C. controller with a right-now up-to-date information only when the incoming plane is concerned.

But, so as not to loose its effectiveness, ATIS should not be unwisely over-used. Airport Authorities should not consider quoting bird hazard on ATIS as a legal umbrella, shifting their responsibility onto aircrew; and should not aim to argue after an accident that warning gave them quietus of their duty. On some ATIS, we can hear "unusual bird situation" most of the time and most of the time we do not see any bird. The result is that pilots do not care of it. To much information is equal to none. If one is shouting "HELP, FIRE" every morning, firemen will not rush when his house will burn.

More, if the risk is actual most of the time, it is not "unusual" as said on ATIS and should be written on A.I.P. as permanent circulation (above mentioned).

. . .

In any case, the crew range of action is often narrow:

When taking-off, the crew can see the birds before or after the Airport controller signals them. Then the pilots can delay the take-

off, waiting for the birds to move away by themselves or be artificialy scattered; or modifie its take-off procedure -i.e. full power instead of de-rated power, cancel noise abatment procedure, alternate routing instead of S.I.D. (Standard Instrument Departure), delay rotation after V2 (normal take-off speed) or else-.

When landing, the range of action is extremely small. Obviously, it is impossible to stop and watch birds behaviour, vaiting for them to clear the way. The pilot has no time -especially if the crew is reduced at two members- to scan the sky and focus on the birds mentioned by the Airport controller. When on short final, where we meet more birds, the pilot neither can change its path nor perform an avoiding action. Or, if he does so, he is compelled to go around, any deviation respect to normal trajectory being leading to a dangerous or impossible landing for an heavy aircraft.

This is to show that it is more important to scare birds out of airfields than to warn pilots that birds are sitting tenants.

. . .

Meanwhile, as a conclusion, it seems useful to conduct an efficent exchange of suitable informations between ground and planes and vice-versa.

Nevertheless, we wish all the birds to be wise enough to avoid collision with planes and, if they fail in doing so, that the consequences, always lethal for them will be minimum for the aircraft and its passengers.

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ADF616054

BSCE 18/COPENHAGEN, MAY 86
WP/14

HELICOPTER BIRD STRIKE RESISTANCE

by

Mr. **A.BREMOND - Airworthiness Office**
AEROSPATIALE - Helicopter Division

Abstract

The hazard created by bird encounters for helicopter occupants does not account for a large percentage of serious accidents. For example no fatal accident due to a bird strike has been recorded, to date, on the Aerospatiale fleet.

However, some cases of cockpit penetration and of engine ingestion have indeed occured. Furthermore the rotors, the sensible and vital part of the helicopter, must be proofed against bird strike effects.

The particularities of helicopter operation, as compared to its fixed-wing brothers, are essentially :

- usage of unprepared areas for take-off and landings
- necessity to provide for large transparent areas for pilot visibility
- low speed - low altitude operations
- no pressurization

The helicopter windscreens are tested to show compliance with the relevant BCAR regulations, and in some cases it has been necessary to improve the initial design.

The air intakes must be consistent with engine regulations regarding bird ingestion or protection. Tests are carried out to develop suitable protection and show compliance with engine regulations.

Rotor blades are not subjected to any regulation, but Aerospatiale has assessed, through similar testing and strain measurements, that bird strikes have only minor effects on blade integrity.

A movie is presented to illustrate typical tests conducted on these three sensitive areas of the helicopter.

ADF616055

BSCE 18/ WP 15
Copenhagen May 1986

ETHOLOGICAL ASPECTS OF PLANE'S PROTECTION AGAINST BIRDS

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Abstract

The birds have more chances to see a plane and to avoid collision than a pilot.The birds are training to extrapolate the direction and speed of a plane flight which exceeds more than two times the speed of birds.This explains why: 1.Migrating and local young birds fall victims of planes 2.Distruction of birds on an aerodrome doesn't decrease the bird danger for planes 3.The number of bird strikes increases relatively in the night,in clouds and when birds flight direction is changed 4.A plane from an indifferent stimulus is becoming a repellent and some time an attractant 5.The means to increase the distance of a plane discovery(landing and flashing lights,lazer)don't always frighten birds away of a plane because a/Birds don't know that a plane represents a danger b/Birds sit on runway or fly back to a plane c/The landing lights in the night render catching action on birds d/Birds attention is distracted when searching for food e/Young birds attack unproportionally large prey f/The flocks of starlings and snipes react by mistake on plane as a bird of prey. Taking into consideration all circumstances favouring conflict situation it is possible to outline concrete means,place and time of their application in order they will not be repeated in future.

The study of birds behaviour in the sight of a plane attracts many researchers especially in the connection with the intention to create an arrangement or means to frighter birds away from a plane or plane's way.

For the majority of birds fluing in the air or habiting on the ground the plane flying far in the sky is an indifferent stimulus. But on the airdroms and on the plants routes where the ways of planes and birds are crossing-both are suffering.

It follows from the analysis of the bird strikes that pilots have noticed birds in the last moment before a strike in 9,7 - 18,3% of all bird strikes.Consequently,a pilot has no possibility to turn a plane away of birds in order to avoid a collision (Jacoby,Beklova,1981).The bird is first to notice the approachement of the tremendous plane with roaring engines and it has more chances to turn away from a plane and to avoid collision.A bird will do that if it learns that a plane represents a danger for it. Such study occurs individually,under the trial and error line,when a bird is thrown away of a plane by an air wave or in group-when a birds sees a plane to drop another birds in the flock. The same training takes place when unskilled bird follows or imitates the skilled bird which flies away in the time from the planes way.

What a bird is learning to ?

Under natural conditions the birds are avoiding collision with some fixed objects by extrapolating its flight speed and direction relatively to this object. But if a bird deals with another bird of the same species flying in opposite direction,then in this case the necessity appears to extrapolate the double speed and direction of bird's rapproachments(Jacoby,1981).The sharp peack of the number of bird strikes takes place just when the speed of plane's flight amounts to 140-150 k/h as soon as the speed of a plane and a bird rapproachements exceeds the double speed of a bird's flight.At airfield the birds learn fast to extrapolate the unusual great speed and direction of a plane's landing or taking-off.As a result the adult local-nesting birds learn to recognize dangerous places and they don't take food and even don't cross runway during plane's flight.The cases are observed when the birds of prey use plane's whirlwinds to get mouses or grasshoppers which are frighten out nearby runway(Jacoby,1977). The birds learn to recognize the plane's kinds being exploited at given airfield.When the new,more powerful kind of a plane is put into operation - the bird strikes are being noticed at first which cease as a result of another birds training.

Such an approach explains why :

1. The birds which see for the first time a plane at close distance fall more often as a victims of a bird strike; that is local young birds on airfield and migrating birds. Because untrained birds can not extrapolate the unusual high speed of a plane's flight(Jacoby,1981).

2.The possibility of bird strikes is increasing when a plane appears unexpectedly from a cloudness, in the darkness,and under the change of its flight direction during the turn when taking-off or landing(Jacoby,1981).

3.The destruction of birds on an airfield doesn't prevent bird strikes. Because it is impossible to destruct all birds migrating across an airfield and because the killed birds are quickly substituted by population nearby airfield which are more dangerous for planes than local birds(Jacoby,1979).

4.A plane is becoming for local airfield birds from an indiffe-

rent stimulus to repellent from runway.This occurs as a result of a bird training - individual or in group.

5.Means increasing the distance of a plane discovering by the birds don't always give the desired effect of frightening birds away from flying plane. If a bird doesn't know that a plane is dangerous it turns aside of it in the last moment.

We will stay more in detail on the last conclusion. The light of landing lights of the landing or taking-off plane in the day can hardly increase essentially the frightening action of a plane on birds and on the distance of a plane discovery by a bird. The more that a plane is becoming a repellent as a result of bird training. Consequently the more distant discovery of a plane by birds helps to avoid bird strike by trained birds only. This is confirmed by lack of statistically reliable data about the influence in the day of switched on landing lights and of the powerful flashes of lights at the end of a wings(Anonymous, 1979,Reed,1982) on the reduction of bird strike number.It was shown in the experiments that the birds in dark cage are orienting their flight at the single source of light which appears in darkness(Liepa,1978). During the night in the full darkness the light of landing lights renders the same catching action on birds. The birds see only the light of a plane's lights and they don't see its silhouette.This is increasing the number of bird hits at various parts of a plane and at the lights themselves. According to our data(Jacoby,1978) there is noted statistically relyable greater number of bird hits at switched-on lights of Tupoleff planes where the lights,when switched-on,move out from fuselage. The area of lights amounts to 1% from the front section of a plane,but the birds hit at the lights in 8 to 15% cases of all night bird strikes, taking into consideration that the lights are switched-on for short time only, during the landing. It was shown(Verheyen,1980) that during the moon nights the probability of bird strikes is decreasing. This is connected apparently with the fact that the bird see the silhouette of an approaching plane and this reduces the catching action of the landing lights. By analogy with that the birds don't hurt against beacon's glasses in the moon nights. The additional lightening of the flying plane's front surface in the night plays the same role(Bellrose,1971). Speaking on means to frighten birds away from flying plane one can not but mention the possibilities to use lazer. The action of lazer's ray on flying bird is not studied. In our opinion the lazer's ray acts on birds eye as sunray flashing. If ray's sparkling on a plane will make it possible for a bird to discover a plane at greater distance - this doesn't mean that a bird will start earlier its maneouvre to avoid a plane. A bird may not notice at all the lazer's ray, the light of the landing and flashing lights if it flies or sits back to coming plane. The last occurs with birds sitting on or nearby runway. The planes are landing and taking-off against the wind.The birds resting on the ground usually are sitting with front against the wind and consequently - back to a plane.They discover the approachment of a plane not according an optical stimulus(the sight of a plane and various lights on a plane),but according to acoustic stimulus - the noise of engines. This explains why the number of bird strikes with broad fuselage planes (B-747 and other)exceeds 6 times more that with narrowfuselage planes(B-707 and other)(Burger,1983). By first ones the noise of engines is lesser and the speed of running is greater than by last ones. Therefore the birds have less time for an avoiding

manoeuvre after hearing broad fuselage plane.It is necessary add that the birds not only sit by front against wind but fly up against wind, that is - fly some time over planes flight(Jacoby, 1974).The drowning of the plane engines sound by contrary wind may have some importance. There is series of factors determining nuances of the birds behaviour and consequently - the visual or acoustic birds reaction to a plane. The observations have shown that sitting gulls are oriented by a head toward wind.But when the wind blows from the sun side - the gulls are turning by back to it(Puigcerver,Rodrigues,Teijeiro,1984). In this case they will see firstly a plane and then will hear it.Undoubtedly the fact may be of importance from what side- that is from the side of the sun or against it - the birds are looking at coming plane. The landing and flashing lights,the lazer ray may be concealed at all against a sun back ground. To number of the factors determining the bird behaviour in the sight of a plane one can add also the distraction of bird attention for food searching. The birds being occupied with food searching at or nearby the runway under conditions of strong noisy pollution at on airfield may hear the noise of the landing or taking off plane or see it in the last moment. In this aspect the flock feeding,flock resting or flock flying birds have an advantage before single feeding, resting or flying birds. There can be within the flock the trained birds which will first fly up or fly away from a flying plane carrying with and training by its behaviour the other unexperienced birds which are not trained to a plane as a danger. Besides,within the flock of feeding birds there is more probable the presence of birds whose attention is not distracted by food searching and who discover the plane's approachment and fly up earlier than other birds. This explains why the number of flock bird strikes amounts to only 22%(Jacoby,1974) and 12% according to Burger(1985).

Considerating bird reaction on planes we will cite some analogies in the behaviour of birds - victims of the bird of prey and on the contrary. For example when a hawk attacks flock of starlings they are performing so called "air ballet" by maneouvring quickly by whole flock to one and to another side.This prevents bird of prey to make purposeful attack against single straggled bird.The utilisation of such tactics by flock of starlings against a plane leads to the fact that mass of birds are knocked down(Jacoby,1972).

The series of strikes committed by eagles,kites and hawks with planes are explained sometime by the fact that these birds attack plane when it flies nearby the nest and below the bird of prey,soaring in the altitude.I know according to my own experience that eagles and kites don't attack a man who reached their nest. Only goshawks attack a man at their nest. May be a bird soaring in termic doesn't make way for a plane. Coming to side it starts to come down. Therefore it may seam to a pilot of the fast approaching plane that a bird attacks plane. There are known observations that young hawks atta by mistake disproportionate great prey. In the same way one can explain the attack committed by an eagle in the autumn against truck driver in Turkmenia which was described by a newspaper.Attacks committed by eagles in the autumn against the low-speed gliders may be attributed to the same cathegory of phenomenons.

These facts show as according to trial-and-error method the birds of prey are trained to get a moving prey.

The examination of bird behaviour when seeing flying plane

shows what a great role is played by birds training and learning to extrapolate the speed and flight direction of a flying plane from the point of view of working out and of efficiency of various means to frighten birds away of a flying plane and to prevent bird strikes.

REFERENCES

Anonymous,1979.Do Birds Love Landing Lights ? Flight,N3654,p.962

Bellrose F.G.1971.The distribution of nocturnal migrants in the air space. Auk,v.88,p.397-424.

Burger J.1983. Jet Aircraft Noise and Bird Strikes: Why more Birds are being Hit. Environmental Pollution(Ser.A) p.143-152.

Burger J.1985. Factors Affecting Bird Strikes on Aircraft at a Coastal Airport. Biol.Conservation,v.33,p.1-28.

Jacoby V.E.1972.Bird Behaviour and Technology.Journ.Obsh.Biology v.33,N3,p.261-273.

Jacoby V.E.1974. Biological Basis of the Bird Strikes Prevention Moscow,"Nauka",165 p.

Jacoby V.E.1977. Plane as a deterrent and attractant. Proc.3th World Conf.on Bird Hazards to Aircraft.Paris,oct. p.345-351.

Jacoby V.E.1978.Wether birds are attracted or distracted by the light of plane's landing lights in the night ? Zool.Journ.v.57,N2,p.304-305.

Jacoby V.E. Is it necessary to destroy birds on aerodromes ? Proc.14th Meet.BSCE;22-26 oct.1979.Hague. 5 p.

Jacoby V.E.1981.Extrapolation of the speed and direction of bird movement. Journ.Obsh.Biology,v.42,N2,p.266-275.

Jacoby V.E, Beklova M.1981. The possibilities for a pilot to prevent an Aircraft-Bird collision.Proc.15th Meet. Bird Strike Comm.Europe,Brussels,May,7 p.

Liepa V.K.1978.Orientation of Robins in the round cages under artificial light. In book:Bird Orientation.Riga. "Zinatne",p.77-179.

Puigcerver M,Rodrigues-Teiejro J.D.1984. Relationship between some activity variables and census in the black headed gull(Larus ridibundus) in regard to certain meteorological parameters. Misc.Zool.,p.225-235.

Verheijen F.J.1980. The Moon: a Neglected Factor in Studies on Collisions of Nocturnal Migrant Birds with Tail Lighted Structures and with Aircraft. Die Vogelwarte,30,p.305-320.

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